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Taxonomic Studies of Podostemaceae of Thailand. 1. *Hydrobryum* and Related Genera with Crustaceous Roots (Subfamily Podostemoideae)

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Recent field work and collections, along with herbarium work, have discovered that three crustaceous-rooted genera with 13 species of subfamily Podostemoideae occur in Thailand. They are two species of *Hanseniella*, one of which (*Ha. smitinandii*) is new, the recently described genus and species, *Thawatchaia trilobata*, and 10 species of *Hydrobryum*, including six new species and one new variety: *Hy. chiangmaiense*, *Hy. kaengsophense*, *Hy. khaoyaiense*, *Hy. loeicum*, *Hy. somranii*, *Hy. tardhuangense*, and *Hy. micrantherum* var. *crassum*. Thailand is a center of distribution for the monophyletic group of *Hydrobryum*, *Hanseniella* and *Thawatchaia*, which are distributed throughout Thailand except in the peninsular. All the species and varieties are described. A key to the species, a table of diagnostic reproductive characters, lists of synonyms and illustrations are provided.

Key words: *Hanseniella*, *Hydrobryum*, Podostemaceae, taxonomy, *Thawatchaia*, Thailand.

Podostemaceae are a family of aquatic angiosperms that occur on rocks in waterfalls and rapids. Vegetative plants grow submerged in swift-running water during the rainy season and become emergent and then wither during the dry season when the water level drops. Generally, the flowers open and seeds are set shortly after emergence. Podostemaceae exhibit specialized adaptations to those extreme environments. The family is characterized by the variously flattened (nearly cylindrical, ribbon-shaped, or crustaceous), creeping (in some species floating), photosynthetic roots (in some species roots are lacking); adhesive rhizoids (root hairs); root-borne adventitious shoots or tufts of leaves; reduced flowers; absence of double fertilization and consequently the presence of a pseudo-embryo sac (Johri *et al.* 1992); tiny seeds and sticky seed coats when wet; reduced embryos; and seedlings usually without an obvious primary shoot apex and primary root. Exceptionally, the crustaceous organ of *Dalzellia* is a leafy shoot. Many of the vegetative and floral characters vary extensively and distinctively in the family (Troll 1941, Rutishauser 1997, Schnell 1998). Discontinuous variation is reflected in the current classification in which nearly 270 species are assigned to nearly 50 genera, which are mostly monotypic or oligospecific (Cook 1996).

The Podostemaceae are generally distributed in the tropics and subtropics. All genera except *Tristicha* are restricted to one super region that includes Africa, America, Asia and northern Australia, and most species are local endemics. The New World is inhabited by 20 genera and about 155 species, while 17 genera and about 75 species occur in Africa and Madagascar; 13 genera and about 40 species are in Asia and Australia (Royen

1951, 1953, 1954, Cusset & Cusset 1988, Cusset 1992, Cook 1996). Recent studies have revealed several new genera and species. The greatest species richness in America is in such large genera as *Apinagia* (50 species), *Marathrum* (25 species), and *Rhyncholacis* (25 species), while the second richest area of Africa is primarily due to the presence of the second largest genus, *Ledermanniella* (44 species). The relatively small number of species in Asia and Australia reflects the small sizes of the genera, of which the largest are *Polypleurum* (7 species [Cusset 1992] or 8 species [Mathew *et al.* 2003]) and *Hydrobryum* (12 species [this paper]). In Asia and Australia, the Podostemaceae range from northern and southern India, Nepal and Sri Lanka east to eastern New Guinea, south to northern Australia, and north to southeastern China and southern Japan. In this super region, southern India and Sri Lanka, with nine genera and about 20 species, is considered to be the center of distribution (Willis 1902, Cusset 1992, Philcox 1996, Mathew & Satheesh 1997, Mathew *et al.* 2001, 2003).

The current knowledge of the Podostemaceae of Thailand is due to the contributions by Warming (1901a, b), Lecomte (1909, 1926), Royen (1957, 1965), Cusset (1973, 1992), and Cusset & Cusset (1988). Thai Podostemaceae comprise two subfamilies (families *sensu* Cusset), seven genera and 10 species (Cusset & Cusset 1988, Cusset 1992). Three of the seven genera, *Hanseniella*, *Hydrobryum*, and *Synstylis* (which has been reduced to *Hydrobryum*), are treated in this paper. Despite the efforts of the authors mentioned above, our understanding of the Podostemaceae of Thailand is far from complete, partly because of poor collections of the inconspicuous and ecologically extreme plants. During field studies in the last five years (Table 1), my colleagues and I collected undescribed and described species at new localities and described species at previously reported localities throughout Thailand. Although further field research is no doubt needed to improve our understanding of the Podostemaceae of Thailand, it has become obvious that Thai Podostemaceae, like the family in southern India and Sri Lanka, are highly diverse.

Thirteen species and one variety assigned to three crustaceous-rooted genera of subfamily Podostemoideae (*Hanseniella*, *Hydrobryum*, and *Thawatchaia* [Kato *et al.* 2004]) (Table 2) are described in this paper. These genera form a monophyletic group (Fig. 1; Kita & Kato, in press). A

TABLE 1. Data of collections of Podostemaceae.

Collection number	Collectors	Date
TL-55–*TL-65*	M. Kato, R. Imaichi, Thawatchai Santisuk & Thawatchai Wongprasert	Jan.1999
TL-101–*TL-107*	M. Kato, R. Imaichi, H. Akiyama & Thawatchai Wongprasert	Mar.2000
TL-201–*TL-211*	M. Kato, S. Koi & Thawatchai Wongprasert	Sep.2000
TL-301–*TL-322*	M. Kato, Y. Kita & Thawatchai Wongprasert	Dec.2000
TL-401–*TL-432*	*401-410*, Y. Kita & Thawatchai Wongprasert; *411-432*, M. Kato, S. Koi, Y. Kita & Thawatchai Wongprasert	Dec.2001
TL-501–*TL-521*	M. Kato, R. Imaichi, C. Tsutsumi & Thawatchai Wongprasert	Mar.2002
TL-601–*TL-604*	M. Kato & Thawatchai Wongprasert	Nov.2002
TL-701–*TL-709*	M. Kato & Thawatchai Wongprasert	Feb.2003
TL-801–*TL-809*	M. Kato, R. Imaichi & Thawatchai Wongprasert	Mar.2003
TL-901–*TL-905*	M. Kato, R. Imaichi, S. Koi & Thawatchai Wongprasert	Jul.2003
TL-1001–*TL-1013*	M. Kato, R. Imaichi, S. Koi & Thawatchai Wongprasert	Dec.2003
TL-1101–*TL-1106*	M. Kato & Thawatchai Wongprasert	Feb.2004
TL-1201–*TL-1204*	M. Kato & Thawatchai Wongprasert	Mar.2004

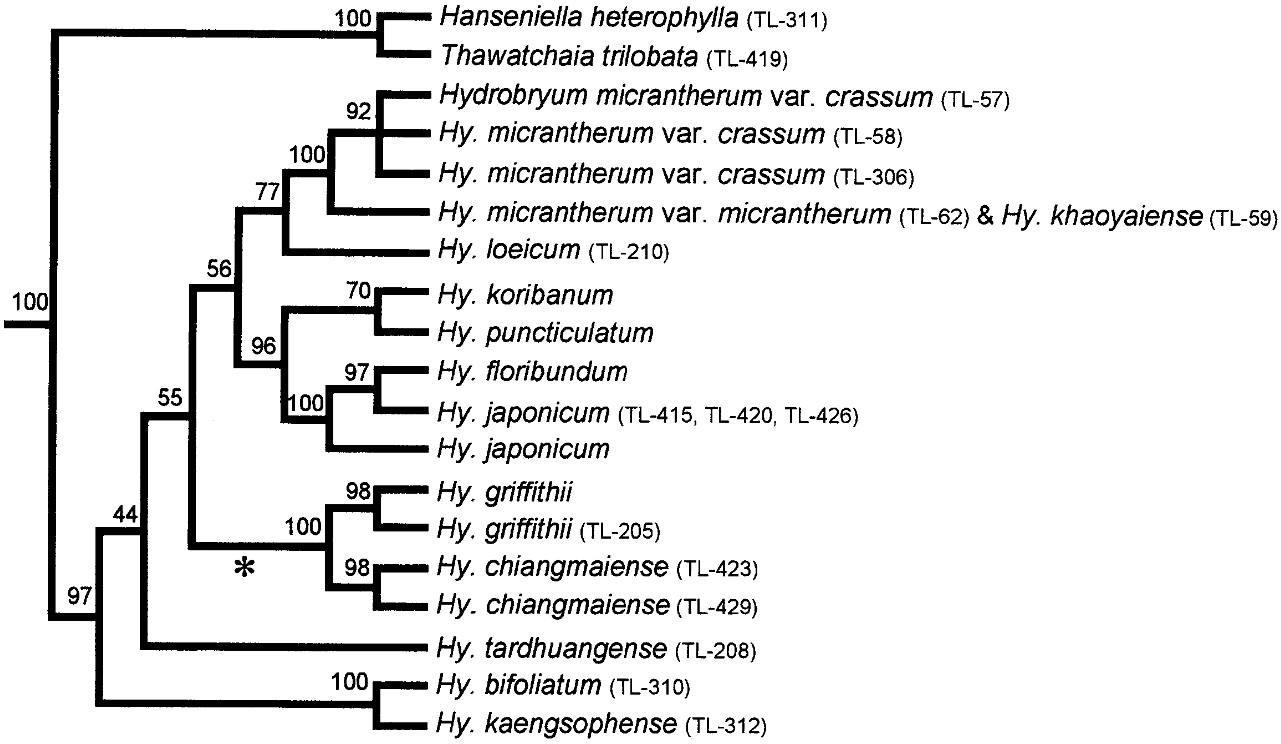
100
Hanseniella heterophylla (TL-311)
Thawatchaia trilobata (TL-419)
92
Hydrobryum micrantherum var. crassum (TL-57)
Hy. micrantherum var. crassum (TL-58)
100
Hy. micrantherum var. crassum (TL-306)
77
Hy. micrantherum var. micrantherum (TL-62) & Hy. khaoyaiense (TL-59)
Hy. loeicum (TL-210)
56
100
70
Hy. koribanum
Hy. puncticulatum
96
97
Hy. floribundum
100
Hy. japonicum (TL-415, TL-420, TL-426)
55
Hy. japonicum
98
Hy. griffithii
44
100
Hy. griffithii (TL-205)
*
98
Hy. chiangmaiense (TL-423)
97
Hy. chiangmaiense (TL-429)
Hy. tardhuangense (TL-208)
100
Hy. bifoliatum (TL-310)
Hy. kaengsophense (TL-312)

FIG. 1. Phylogenetic tree of *Hydrobryum, Hanseniella* and *Thawatchaia*. Adapted from part of Kita & Kato's (in press) *matK* strict consensus tree, using species names described here for unidentified species. Numbers with prefix TL in parentheses are numbers of vouchers cited in this paper. Asterisk indicates position where *Hy. somranii* diverges (Y. Kita unpubl. data).

paper dealing with the remainder of Thai Podostemaceae (Tristichoideae and Podostemoideae with subcylindrical or ribbon-like roots) will be published in this journal. These papers are precursors for the treatment of the family for the Flora of Thailand.

Materials and Methods

Specimens were collected in various places in Thailand during extensive field studies since 1999. They were usually fixed in FAA (formalin : acetic acid : 50% alcohol = 5 : 5 : 90 (v/v) and sometimes also dried. Vouchers are deposited in the Forest Herbarium, Department of National Parks, Wildlife and Plant Conservation, Bangkok (BKF), and in the Herbarium, University of Tokyo (TI). They are recorded below without indication of herbarium. I also examined specimens in other herbaria: Aarhus University (AAU), the Department of Agriculture, Bangkok (BK), the University of Copenhagen (C), the Royal Botanic Gardens, Kew (K), Kyoto University (KYO), Herbier National de Paris, Muséum National d'Histoire Naturelle (P), and the National Science Museum (TNS). Dr. T. Yamada examined specimens housed in Nationaal Herbarium Nederland (L).

Since publishing a molecular phylogeny of Podostemaceae deduced from *matK* nucleotide sequences (Kita & Kato 2001), we have continued to accumulate molecular data for an increasing number of taxa. Part of the results (Kita & Kato 2004) are in press and the remaining results will be published elsewhere. Molecular data are useful for identifying and recognizing species of the crustaceous-rooted *Hydrobryum* and related genera, because it is often not easy to identify the morphologically simple species with certainty. The present paper recognizes species and varieties from a consensus of morphological and molecular data. Since

Key to Species and Varieties of Thailand

1. Flowering shoots erect; bracts in 4 ranks, dimorphic, ventrals (facing root) bilobed, dorsals simple; ovules 4-6 per locule.......................................2
  2. Capsule 2-2.5 mm long, ribs 12-16 ....1. *Hanseniella heterophylla*
  2. Capsule 1.5-2 mm long, ribs 8 ....2. *Hanseniella smitinandii*
1. Flowering shoots appressed or oblique (*Thawatchaia*), or rarely only flowers erect (*Hydrobryum somranii*); bracts in 2 ranks, uniform, simple or trilobed; number of ovules various (4-30) 3
  3. Bracts trilobed with lobes acute ....3. *Thawatchaia trilobata*
  3. Bracts simple with tips obtuse or sometimes acute or acuminate 4
    4. Stamens 2 with filament forked 5
      5. Bract linear-lanceolate, pointed at apex; stigmas unequal..................6
        6. Root (crust) ca. 0.5 mm thick, not markedly raised around tufts of leaves; bracts 2-3; stigmas unequal, forked below middle ....4. *Hydrobryum bifoliatum*
        6. Root (crust) up to ca. 1 mm thick, prominently raised around tufts of leaves; bracts 4-6; stigmas markedly unequal, forked above middle ....5. *Hydrobryum kaengsophense*
      5. Bract deltoid, elliptic or ovate, obtuse (not pointed) or acute at apex; stigmas equal or subequal 7
        7. Leaves oblique or appressed, tough; bract deltoid, acute at apex; spathella split longitudinally, stigmas subequal ....6. *Hydrobryum tardhuangense*
        7. Leaves patent, soft (but tough in *H. khaoyaiense*); bract ovate or elliptic, obtuse at apex; spathella ruptured irregularly (if split longitudinally, ovary 1-locular; *H. somranii*), stigmas equal 8
          8. Stigma cristate, ovules 20-30 per locule..................7. *Hydrobryum griffithii*
          8. Stigma entire or subentire, ovules 4-20 per locule 9
            9. Capsule ribs 16-20; ovules 4-7 per locule ....8. *Hydrobryum loeicum*
            9. Capsule ribs 12-14; ovules 6-20 per locule (per septum in 1-locular ovary) 10
              10. Bracts 2-4, spathella ruptured longitudinally; flowers and fruits erect; ovary 1-locular; ovules 6-12 per septum..................9. *Hydrobryum somranii*
              10. Bracts 4(-6), spathella ruptured irregularly near apex; flowers and fruits, like flowering shoots, appressed or oblique; ovary 2-locular; ovules 12-20 per locule..................11
                11. Stigma subentire, oblong or narrowly deltoid-lanceolate, emarginated, truncate, or obtuse at tip; ovules 12-20 on septum surface except in small lower central area; leaves 10-20 mm long ....10. *Hydrobryum chiangmaiense*
                11. Stigma entire, linear, pointed at tip; ovules 11-15 on marginal surface of septum; leaves to 3 mm long..................11. *Hydrobryum japonicum*
    4. Stamen 1 with simple filament..................12
      12. Ovary 2-locular; placentation axile; leaves somewhat tough ....12. *Hydrobryum khaoyaiense*
      12. Ovary 1-locular; placentation pseudo-central; leaves soft..................13
        13. Root (crust) 0.1-0.2 mm thick; bracts 2-4; ovary ca. 1.5 mm long; ovules 9-13 per septum surface ....13a. *Hydrobryum micrantherum* var. *micrantherum*
        13. Root (crust) 0.2-0.3 mm thick; bracts 3-5; ovary 1.5-2 mm long; ovules 13-23 per septum surface ....13b. var. *crassum*

some species were unidentified in the phylogeny published by Kita & Kato (in press), the phylogenetic tree is redrawn with the addition of the names of species described in this paper (Fig. 1).

Species of the three genera treated here are distinguished mainly by floral characters (Table 2; see Key and Figures). The terminology of the flower of Podostemaceae is unusual because of the specialized body plan and reduced flowers in the family. *Bract* is used as the term for a leaf on a flowering shoot. *Peduncle* is used for the stalk under a flower or ovary proper (Cusset 1992). The tepals and stamens are usually inserted at or near the base or middle of the relatively short peduncle in the crustaceous-rooted Podostemoideae treated in this paper, although they are inserted on the uppermost part of the peduncle in most other Podostemaceae. Therefore, the *peduncle* is described as the *ovary stalk* (*peduncle*). The *tepals* and *stamens* are inserted similarly at various positions of the ovary stalk (peduncle) in Southeast Asian (Laos; Kato & Fukuoka 2002) and African Podostemaceae (Taylor 1953, Cusset 1987). The *stamen* is simple or branched; in the latter case the *filament* is simple basally and dichotomous at varying levels into two upper filaments with *anthers* at the tip. The style is absent or reduced and, because of its inconspicuous size, the pistil is described here using the terms *ovary* and *stigma*; for instance, a pistil with a reduced style is described as an ovary having forked stigmas. The *spathella* is a special envelope (whose homology is uncertain) that covers the flower bud and ruptures at anthesis.

Taxonomy

Hanseniella C. Cusset

Bull. Mus. Natl. Hist. Nat., B, Adansonia 14(1): 36, 1992. Type: *Hanseniella heterophylla* C.Cusset.

Root crustaceous, irregularly lobed, green when fresh, adhering to rock surfaces by rhizoid pads, with tufts of leaves scattered on dorsal surface; leaves several per tuft, linear. Flowering shoots scattered on dorsal surface of thickened root, erect or suberect; flowers solitary; bracts thick, dimorphic, arranged in 4 ranks (2 dorsal, 2 ventral), to 7 per rank, upper ones gradually larger; ventral bracts (facing root) ovate, bilobed 1/2 way to base, lobes obtuse or lower ones acute; dorsal bracts simple, uppermost ones bilaterally asymmetric, rectangular, apex subtruncate or round, lower ones symmetric, subacute, all carinate abaxially; flower bud covered by spathella, spathella irregularly ruptured near apex at anthesis; tepals 2, inserted above base or near middle of ovary stalk (peduncle), on both sides of stamen; stamens 2, forked above middle, longer than pistils; ovary 1, locules 2, ellipsoid, slightly flattened; stigmas 2, equal; ovules 4-6 per locule, large (ca. 1 mm × 0.5 mm); capsule stalked, ellipsoid, flattened, with 8 or 12-16 ribs (8 and 4-8 additional ribs), dehiscing by 2 equal valves. 2 species; both endemic to Thailand.

Distribution: Thailand.

Notes: *Hanseniella* is similar to *Thawatchaia* in the lobed bract and in having fewer than 10 large ovules per locule, although the bracts are arranged in 4 ranks, bilobed or simple in the former, and in 2 ranks and trilobed in the latter. *Hanseniella* differs from *Hydrobryum* in having more numerous, dimorphic (bilobed and simple) bracts in 4 ranks, and fewer (8-11) and larger ovules per ovary. Similarly, fewer ovules are seen in *Hy. loeicum*, but it differs from *Hanseniella* in the uniform, simple, fewer bracts in 2 ranks, as is usual in *Hydrobryum*, and the 16-20 capsule ribs. It is noted that in the lobed bracts *Hanseniella* and *Thawatchaia* are similar to *Cladopus*, which has subcylindrical or ribbon-like roots, and which is sister to a clade of these genera and *Hydrobryum*. The 4 ranks of bracts of *Hanseniella*, like those of *Willisia*, are unusual in Asian Podostemoideae.

Cusset (1992) considered *Hanseniella* to be monotypic and described the capsule as having 8

TABLE 2. Comparison in floral characters among species of *Hanseniella*, *Thawatchaia* and *Hydrobryum*. hetero = *Hanseniella heterophylla*; smiti = *Ha. smitinandii*; triloba = *Thawatchaia trilobata*; bifolia = *Hydrobryum bifoliatum*; kaengs = *Hy. kaengsophense*; tardh = *Hy. tardhuangense*; griffith = *Hy. griffithii*; loei = *Hy. loeicum*; somran = *Hy. somranii*; chiang = *Hy. chiangmaiense*; japon = *Hy. japonicum*; khaoya = *Hy. khaoyaiense*; micran = *Hy. micrantherum*.

Characters	hetero	smiti	triloba	bifolia	kaengs	tardh	griffith	loei	somran	chiang	japon	khaoya	micran
Flowering shoot*1	erect	erect	appress	appress	appress	appress	appress	appress	appress	appress	appress	appress	appress
Flower	erect	erect	oblique	oblique	oblique	oblique	oblique	oblique	erect	oblique	oblique	oblique	oblique
Ranks of bracts	4	4	2	2	2	2	2	2	2	2	2	2	2
No. of bracts	≤24	≤ 28	8-12	2-3	4-6	4-6	5-6	4-6	2-4	4	4-5	2-3	2-4*9 3-5*9
Bract conformity*2	dimorph	dimorph	uniform	uniform	uniform	uniform	uniform	uniform	uniform	uniform	uniform	uniform	uniform
Shape of bract	bilobed/simple	bilobed/simple	trilobed	simple	simple	simple	simple	simple	simple	simple	simple	simple	simple
Bract tip*3	obtuse	obtuse	acute	acumin	acumin	acute	obtuse	obtuse	obtuse	obtuse	obtuse	obtuse	obtuse
Spathella*4	irr	irr	irr	irr	irr	irr	irr	irr	longi	irr	irr	irr	irr
Stamens	2	2	2	2	2	2	2	2	2	2	2	1	1
Ovary locule	2	2	2	2	2	2	2	2	1	2	2	2	1
No. of ovules*5	4-6	4-6	7-9	17-25	16-18	11-17	22-29	4-7	6-12	12-20	11-15	17-23	9-13*9 15-23*9
Ovule disposition*6	M	M	M	M+C	M+C	M+C	M+C	M	M	M+C	M	M	M
Length of stigma*7	equal	equal	equal	uneq	uneq	subeq	equal	equal	equal	equal	equal	equal	equal
Stigma*8	entire	entire	entire	entire	entire	entire	cristate	entire	entire	subent	entire	entire	entire
No. of capsule ribs	12-16	8	8-10	14-20	12-14	12-14	12-14	16-20	12-14	12-14	12-14	12-14	12-14

*1 appress = appressed; *2 dimorph = dimorphic; *3 acumin = acuminate; *4 irr = ruptured irregularly near apex, longi = longitudinally split; *5 number of ovules per locule, but per septum surface in a 1-locular ovary; *6 M = on marginal surface of septum, M+C = on septum surface except in lower central area; *7 uneq = unequal; *8 subent = subentire; *9 top = var. *micrantherum*, bottom = var. *crassum*.

ribs. Many capsules recently collected from Tung Salaeng Luang, the type locality of *Ha. heterophylla*, usually have 14-16 ribs with 8 thick ribs and to 8 additional shorter, thin ribs. The capsules of the Phu Rua populations also have 12-16 ribs. In comparison, *Smitinand & Abbe 6304*, collected at Fang, Chiang Mai, which was cited as an authentic specimen of *Ha. heterophylla sensu* Cusset, has capsules with 8 ribs and accords with Cusset's description and illustrations of the species (Cusset 1992, fig. 6). Analysis of *Ha. heterophylla sensu* Cusset (1992) resulted in its separation into two species.

1. Hanseniella heterophylla C. Cusset (*emend.* M.Kato), Bull. Mus. Natl. Hist. Nat., B, Adansonia 14(1): 36, 1992. Type: Tung Salaeng Luang, Northern Thailand, fl. Feb., *Hansen 11569* (C). (Fig. 2)

Root crustaceous, irregularly lobed, lobe usually 5-10 mm wide; leaves several per tuft, linear, terete, to 2 mm long. Flowering shoots 2-3 mm long, erect or suberect, flowers solitary at tip; bracts thick, dimorphic, arranged in 4 (2 dorsal, 2 ventral) to 6 per rank, upper ones gradually larger, bracts in adjacent ranks occasionally connate; ventral bracts (facing root) ovate or obovate, ca. 2 mm × 2 mm, bilobed 1/2 way to base, lobes obtuse or lower ones acute; dorsal bracts simple, uppermost ones bilaterally asymmetric, rectangular, subtruncate or round, 2 mm × 1.5 mm, lower ones symmetric, subacute, carinate abaxially; flower bud covered by spathella, spathella thick, with 2 or 3 ridges, irregularly ruptured near apex at anthesis; ovary stalk (peduncle) 2-3 mm long; tepals 2, attached above base or near middle of ovary stalk, on both sides of stamen, linear, ca. 3 mm long; stamens 2, forked above middle, to 6 mm long, longer than pistil; ovary 1, locules 2, ellipsoid, slightly flattened, ca. 2.5 mm × 1 mm, protruding from bracts at maturity; stigmas 2, forked near base, equal, curved or erect, ca. 0.4 mm long, linear, pointed or obtuse; ovules 4-6 per locule, large (ca. 1 mm × 0.5 mm); capsule stalked (stalk 2-4 mm long), far beyond bracts, ellipsoid, flattened, 2-2.5 mm long, with 12-16 ribs (up to 8 additional shorter, thinner ribs between 8 thick ribs).

Distribution:Thailand (Northern, Northeastern).

Notes: The International Code of Botanical Nomenclature (Greuter *et al.* 2000) requires that *Hanseniella heterophylla* be typified by *Hansen 11569* (C), as originally designated by Cusset (1992). Because Cusset's (1992) original description and illustrations do not match specimens collected at the type locality and likely the holotype (not seen), a fully emended description is provided above. The most significant alteration is in report of the larger number of ribs on the capsule (12-16 instead of 8) in association with the larger ovary.

Specimens examined: Northern Thailand: Kaeng Sopha waterfall, Tung Saleng Luang Natl. Park, Phitsanulok, 400 m alt., 16°52'N 100°50'E, fl. fr. Dec., *Kato et al. TL-311*. Northeastern Thailand: San stream, Kaeng Samsawan, Phu Rua, Loei, 470 m alt., 17°28'N 101°16'E, fr. Feb., *Kato & Wongprasert TL-1104*, *Wongprasert s.n.*

2. Hanseniella smitinandii M. Kato, **sp. nov.** (Fig. 3)

A *Ha. heterophyllae* capsulis parvioribus, 8-costatis differt.

Type: Fang, Chiang Mai, Northern Thailand, 800 m alt., fr. Dec. 1959, *Smitinand & Abbe 6304* (holo BKF; iso BK, C, L).

Root crustaceous, irregularly lobed, 0.2-0.3 mm thick when dried. Flowering shoots 2-4 mm long, suberect or oblique, flowers solitary at tip; bracts thick, dimorphic, arranged in 4 ranks (2 dorsal, 2 ventral), to 7 (or 8) in each rank, upper ones gradually larger; ventral bracts ovate, ca. 2 mm × 2 mm, bilobed 1/2 way to base, lobes obtuse or lower ones acute; dorsal bracts simple, uppermost ones bilat-

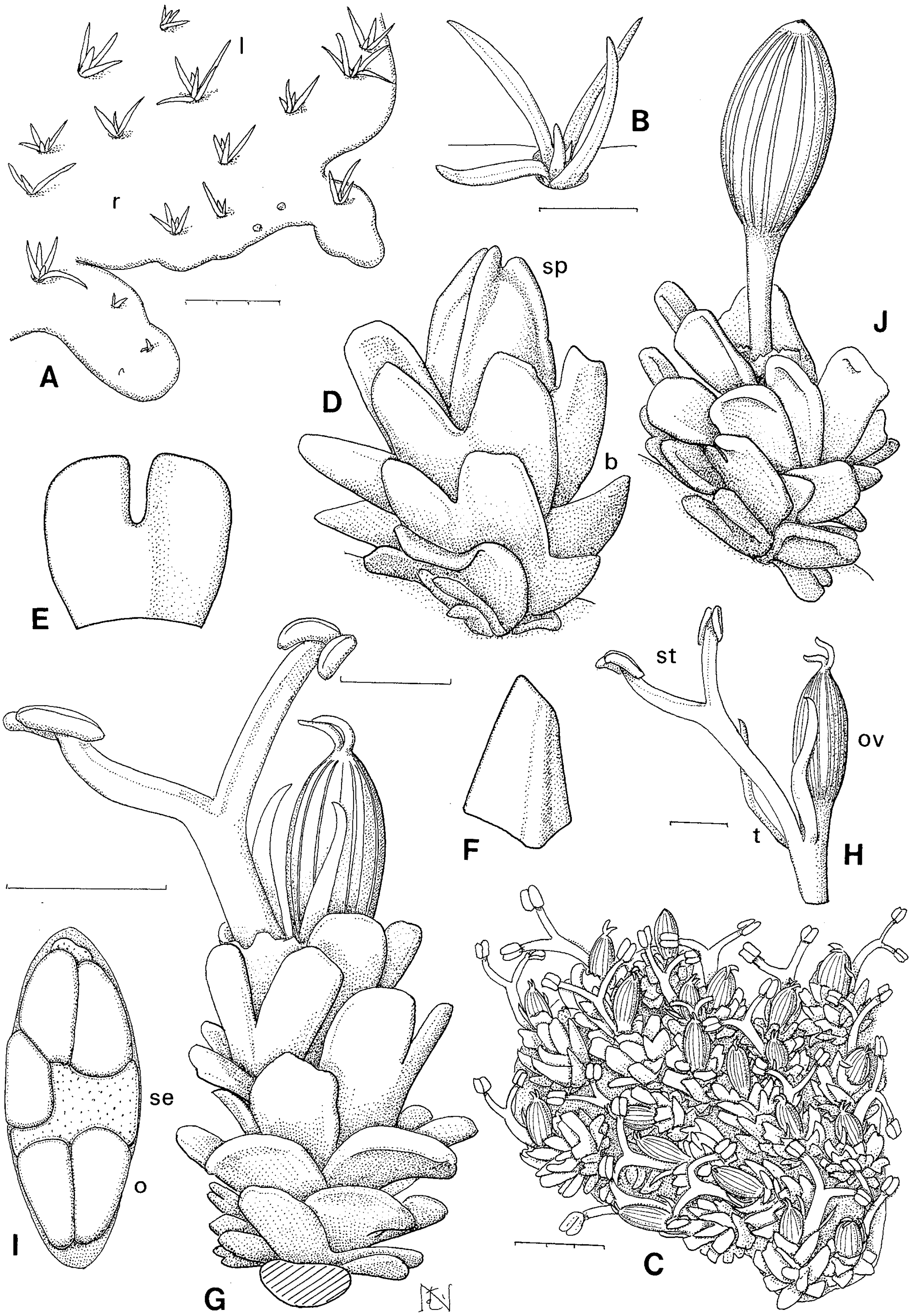

FIG. 2. *Hanseniella heterophylla* (*Kato et al. TL-311*). A. Crustaceous root with tufts of leaves on dorsal surface. B. Tuft of leaves. C. Flowering shoots on root. D. Flower bud covered by spathella above bracts. E. Ventral bract. F. Dorsal bract. G. Flowering shoot; ventral view. Cross section of shoot base is seen. H. Flower at anthesis. I. Ovary septum with ovules. J. Fruit on shoot. *b*, bract; *l*, leaf; *o*, ovule; *ov*, ovary; *r*, root; *se*, septum; *sp*, spathella; *st*, stamen; *t*, tepal. Scales bars = 3 mm for A, C; 1 mm for B, D-J.

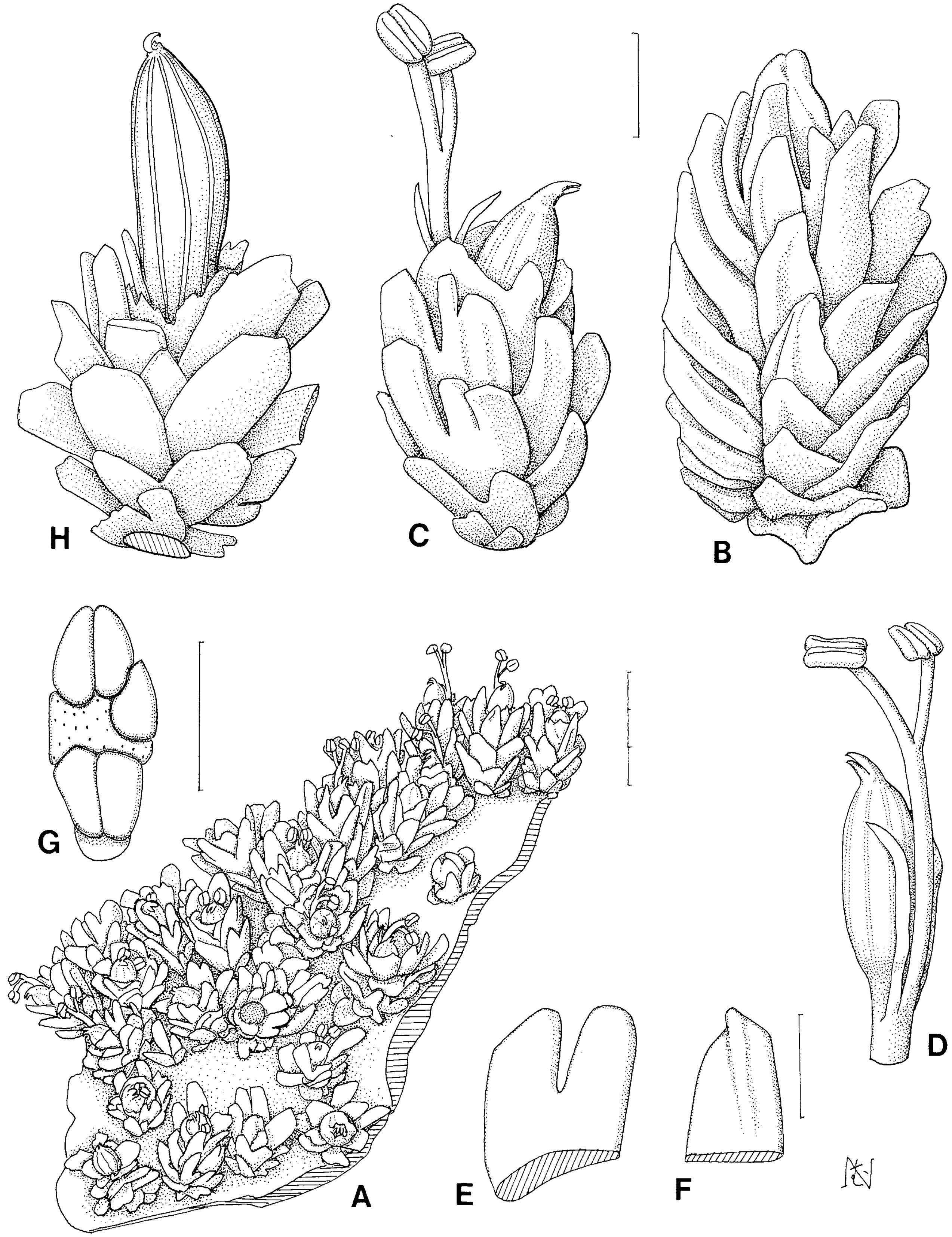

FIG. 3. *Hanseniella smitinandii* (*Smitinand & Abbe 6304* [C], dried specimen). A. Crustaceous root with flowering shoots on dorsal surface. B. Flower bud covered by spathella above bracts. C. Flowering shoot. D. Flower. E. Ventral bract. F. Dorsal bract. G. Ovary septum with ovules. H. Fruit on shoot. Scales bars = 3 mm for A; 1 mm for B-H.

erally asymmetric, rectangular, apex subtruncate or round, 2 mm × 1 mm, lower ones symmetric, subacute, all carinate abaxially; flower bud covered by spathella, spathella thick, with 2 or 3 ridges, irregularly ruptured near apex at anthesis; ovary stalk (peduncle) ca. 2 mm long; tepals 2, attached near middle of ovary stalk (peduncle), on both sides of stamen, linear, ca. 1.5 mm long; stamens 2, forked above middle, to 4 mm long, longer than pistil; ovary 1, locules 2, ellipsoid, slightly flattened, to 2 mm × 1 mm, protruding from bracts at maturity; stigmas 2, forked near base, equal, curved or erect, ca. 0.4 mm long, linear, pointed or obtuse; ovules 4-6 per locule, large; capsule stalked (stalk ca. 3 mm long), far beyond bracts, ellipsoid, flattened, 1-2 mm × 0.4-0.7 mm, ribs 8.

Distribution: Thailand (Northern).

Notes: This species is clearly distinguished from *Hanseniella heterophylla* by the smaller capsule with 8 ribs. Cusset's (1992) descriptions and illustrations of *Ha. heterophylla sensu* Cusset match *Ha. smitinandii* rather than *Ha. heterophylla* emended (see Notes on *Hanseniella* above).

Thawatchaia M. Kato, Koi & Y. Kita

Acta Phytotax. Geobot. 55: 66, 2004. *Type*: *Thawatchaia trilobata* M. Kato, Koi & Y. Kita.

Distribution: Thailand.

Notes: Description is the same as that of the type and sole species below. This genus was described by Kato *et al.* (2004) as an addition to the Podostemaceae of Thailand and is distinguished from all other crustaceous-rooted genera by the trilobed bracts in two ranks.

3. Thawatchaia trilobata M. Kato, Koi & Y. Kita, Acta Phytotax. Geobot. 55: 66, f. 1, 2, 3A-C, 2004.

Type: Mae Wang stream, north of Doi Inthanon Natl. Park, Chiang Mai, Northern Thailand, 450 m alt., 18°38'N 98°43'E, fl. & fr., Dec. 24, 2003, *M. Kato, R. Imaichi, S. Koi & T. Wongprasert TL-1003* (holo BKF!; iso TI!). (Fig. 4)

Root crustaceous (foliose, Kato *et al.* 2004), irregularly lobed, ca. 0.3 mm thick, with tufts of leaves scattered on dorsal surface, patent; leaves 2-5 per tuft, in 2 ranks, linear, sheathed at base, terete apically, 1-3 mm long. Flowering shoots bearing solitary terminal flowers, scattered on dorsal surface of root, appressed or sometimes strongly oblique to root surface, rarely ascending, 2-3 mm long, flowers strongly oblique; bracts thick, 2-ranked, 4-6 per rank, upper ones trilobed or uppermost bract sometimes bilobed with ventral lateral lobe reduced, 1.5-3 mm long, lobes acute, ventral lobes smaller, lower bracts smaller than upper, ca. 1 mm long with small round lobes at base; spathella thin, mucronate with mucrones ca. 0.3 mm long, ruptured irregularly near apex; ovary stalk (peduncle) extruded from spathella, 2-2.5 mm long; tepals 2, on both sides of stamen, borne below middle of ovary stalk, 2-3.5 mm long, reaching above middle of ovary, linear; stamens 2, connate near or above middle of filament, 3-5(-7) mm long, longer than ovary, anthers oblong-elliptic, ca. 1.2 mm long, withered shortly after rupturing of spathella; ovary 1, stalked (stalk ca. 2 mm long), ellipsoid, 2.5-3.5 mm long, locules 2, red-purple when fresh; stigmas 2, forked near base, equal, linear, entire, pointed, 0.6-1 mm long, withering shortly after extruding from spathella; ovules 7-9(-11) per locule, large, borne on marginal surface of septum or on whole septum surface except in small lower central area; capsule stalked (stalk 2-3 mm long), ellipsoid, flattened, 2-3 mm × 1 mm, ribs 8-10, dehiscing by 2 equal valves.

Distribution: Thailand (Northern).

Notes: *Thawatchaia* is similar to *Hanseniella*, *Hydrobryum*, part of *Diplobryum* and part of *Zeylanidium* in the crustaceous roots with tufts of leaves and flowering shoots scattered on the dorsal surface, and the flower composed of a spathella, two linear tepals, two stamens on a common filament (andropod) (or rarely one in *Hydrobryum*), and a bilocular ovary (rarely 1 in *Hydrobryum*) with two stigmas. *Thawatchaia* is the most similar

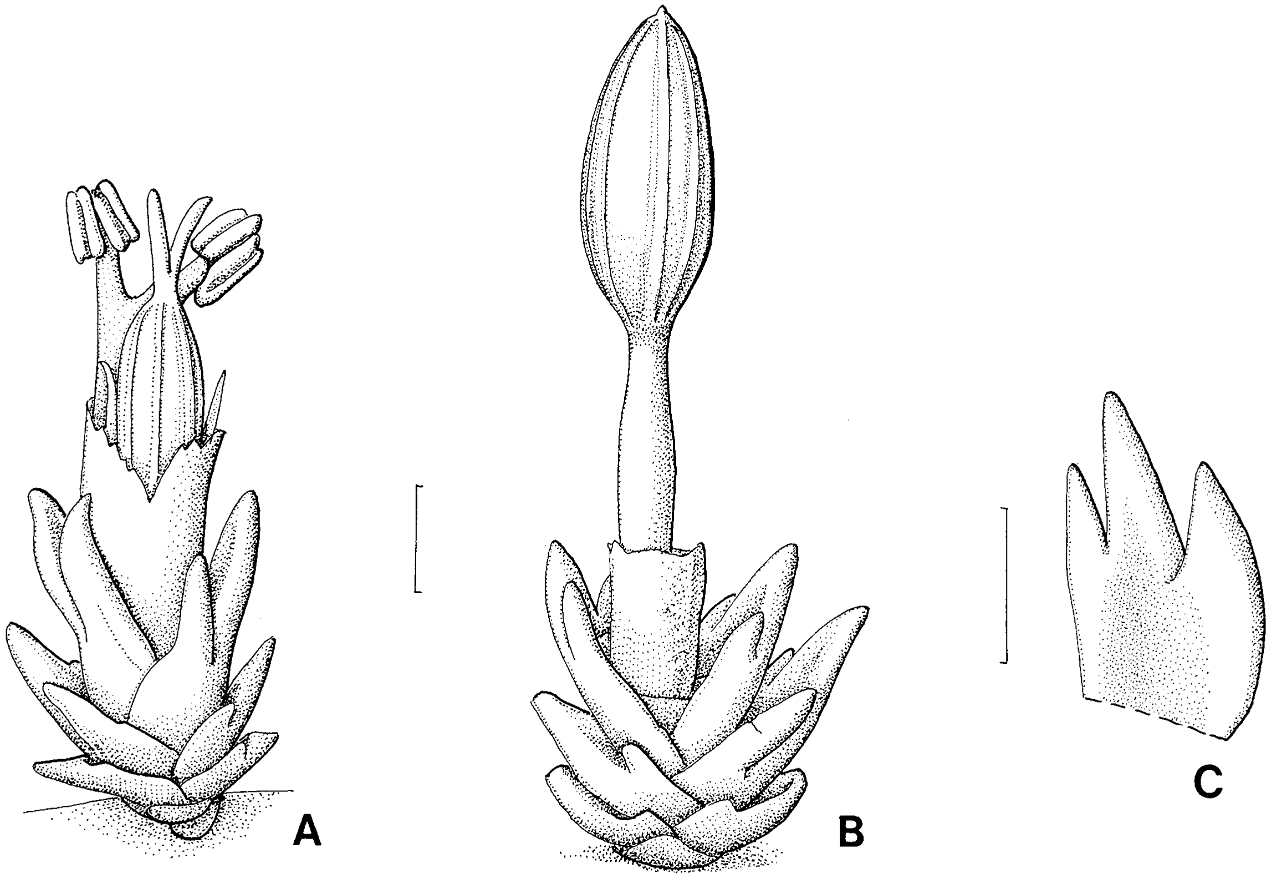

FIG. 4. *Thawatchaia trilobata* (*Kato et al. TL-1003*). A. Flowering shoot at anthesis. B. Fruit. C. Bract. Scales bars = 1 mm. Adapted from Kato *et al.* (2004).

to *Hanseniella* among the crustaceous-rooted genera in the 10 or more lobed bracts and fewer than 10 ovules per locule. *Thawatchaia* differs from *Hanseniella*, however, in the flowering shoots appressed or oblique to the root, the bracts arranged in 2 ranks and uniform and usually trilobed, the spathella thinner, and the ovules 7-9 per locule.

Thawatchaia is also similar to *Hydrobryum* in the flowering shoots being oblique or appressed to the root surface, the bracts in 2 ranks and uniform, and the spathella thin and ruptured irregularly near the apex. It differs in the bracts being thicker, 4-6 per rank and trilobed (*vs*. 1-4, simple in *Hydrobryum*), the ovules 7-9 per locule (*vs*. usually more than 10 in *Hydrobryum* except in *H. loeicum* and *H. somranii* with 4 or 6 ovules), and the capsule ribs 8-10.

Molecular data show *Thawatchaia* branching from near the divergence of *Hanseniella* and *Hydrobryum* (Fig. 1).

Other specimens examined: Northern Thailand: Mae Klang waterfall, Doi Inthanon, Chiang Mai, 450 m alt., 18°29'N 98°40'E, fl. buds, & st. Dec. & Mar., *Kato et al. TL-419*, *502*, *503*; Wang Kwai waterfall near Forest Protection Station above Mae Klang waterfall, Doi Inthanon, Chiang Mai, 450 m alt., 18°30'N 98°40'E, fl. & fr. Mar., *Kato et al. TL-804*; Mae Wang stream, north of Doi Inthanon Natl. Park, Chiang Mai, 450 m alt., 18°38'N 98°43'E, fl. & fr., Mar., *Kato et al. TL-809*.

Hydrobryum Endl.

Gen. Pl. 1375, 1841, *p.p.*; Tul., Ann. Sci. Nat. ser. 3, 11: 103, 1849; Arch. Mus. Paris 6: 137, 1852; Hook. f., Fl. Brit. Ind. 5: 63, 1886; Willis, Ann. Roy. Bot. Gard. Peradeniya 1: 225, 1902; Engl., Nat. Pflanzenfam. 2nd ed. 18a: 52, 1930; Ohwi, Fl. Jap. 393, 1965; Wu, Fl. Reipubl. Popularis Sin. 24: 2, 1988; Cusset, Bull. Mus. Natl. Hist. Nat., B, Adansonia 14(1): 44 1992; Kato & Kita, Acta Phytotax. Geobot. 54: 94, 2003. Type: *Hydrobryum griffithii* (Wall. ex Griff.) Tul.

Hydroanzia Koidz., Acta Phytotax. Geobot. 4: 26, 1935. Type: *Hydroanzia floribunda* (Koidz.) Koidz.

Synstylis C.Cusset, Bull. Mus. Natl. Hist. Nat., B, Adansonia 14(1): 26, 1992. Type: *Synstylis micranthera* (P.Royen) C.Cusset.

Root crustaceous, irregularly lobed, with tufts of linear leaves scattered on dorsal surface; pads of adhesive rhizoids on ventral surface. Flowering shoots scattered on dorsal surface of root, appressed, flowers solitary at tip; bracts uniform, ovate to linear, 2-8, in 2 ranks; flower bud covered by spathella, spathella ruptured irregularly near apex or rarely longitudinally at anthesis; ovary stalk (peduncle) short, with sepals and stamen inserted from base to near middle of stalk; tepals 2, on both sides of stamen, linear; stamens 1 or 2, if 2, branched from common andropod; ovary 1, oblique, appressed, or rarely erect (*Hydrobryum somranii*), ellipsoid, flattened, locules1 or 2; stigmas 2, equal or unequal; ovules borne on septum surface or on marginal surface of septum except in small lower central area, placentation axile or pseudo-central; capsule shortly stalked, ellipsoid, flattened, ribs 12-20, dehiscing by 2 equal valves. Ca. 12 species; 10 species in Thailand.

Distribution: Thailand, northern India, Nepal, Bhutan, south-central China, northern Vietnam, southern Japan.

Notes: Cusset (1992) recognized three species of *Hydrobryum* in the broad sense, all of which are distributed in Thailand. Six new species are added here and *Synstylis micranthera* has been moved to *Hydrobryum* (see below), resulting in the 10 species of the genus in Thailand.

The vegetative morphology of *Hydrobryum* is simple and rather uniform. The species are distinguished from each other mainly by the form of the bracts, the number of stamens, the number of ovules, the number of ovary locules, placentation, form of the stigmas, and the number of ribs on the capsule (Table 2; see also Key). The monotypic genus *Synstylis*, with only *S. micranthera*, was recognized by Cusset (1992) as independent from *Hydrobryum* by its single, simple stamen and unilocular ovary with pseudo-central placentation. Molecular phylogeny indicates that *Hydrobryum* and *Synstylis* form a monophyletic group, and *S. micranthera* is most closely related to *H. loeicum* among the species examined (Kita & Kato 2001, Y. Kita unpubl. data), providing the basis for combining *S. micranthera* (the type species of *Synstylis*) with *Hydrobryum* (Cook & Rutishauser 2001).

Hydrobryum is the largest genus of Podostemaceae in Thailand and includes many endemics. Two species (*Hy. griffithii* and *Hy. japonicum*) extend to other regions. It is noted that *H. bifoliatum* and *H. kaengsophense* are basal in the *Hydrobryum* clade, and, like *Hanseniella* and *Thawatchaia*, which are sister to *Hydrobryum* (Fig. 1), are endemic to Thailand. These distribution patterns and phylogeny suggest that *Hydrobryum* has diversified in Southeast Asia, and, in particular, in Thailand.

Hydrobryum can be distinguished from *Hanseniella* and *Thawatchaia* by its uniform, simple, entire bracts borne in 2 ranks. There are additional crustaceous-rooted species from southern India and Sri Lanka in other genera, e.g. *Polypleurum* (*P. filifolium*), *Willisia* (*W. selaginoides*), and *Zeylanidium* (*Z. olivaceum*, *Z. maheshwarii*). Similarity in the crustaceous roots is the result of convergence.

Diplobryum is a genus characterized primarily by the 20 ribs of the capsule and was considered to comprise two species, *D. minutale* C.Cusset of Vietnam and *D. ramosum* C.Cusset of Laos (Cusset 1972, 1973, 1992). The type species of *Diplobryum* *minutale* is similar to *Hydrobryum* in the crustaceous root with tufts of leaves on the surface, two stamens united into a common andropod, bilocular ovary, and capsules dehiscing by two equal valves. In sharp contrast, *D. ramosum* has a cylindrical, branched, floating axes (shoots?). Recently, Kato & Fukuoka (2002) described two new species of *Diplobryum* from Laos, one of which (*D. vientianense*) is similar to *D. minutale* in the crustaceous root, longitudinally split, persistent spathella, and 18-20 capsule ribs. *Hy. bifoliatum* and *Hy. loeicum* also have 16-20 ribs similar to those of *Diplobryum*. In contrast, *D. minutale* and *D. vientianense* have much longer ovary stalks (peduncles) than most species of *Hydrobryum*, and the tepals and stamens are inserted near or below the middle of the ovary stalk. In these characters and in the longitudinally split spathella, they are similar to *H. somranii*, although they differ in the number of ovary locules and capsule ribs. To determine the systematic position and naturalness of the apparently heterogeneous genus *Diplobryum*, further phylogenetic analysis is necessary. It would be interesting to know if the crustaceous roots of *Diplobryum* and *Hydrobryum* evolved from a common ancestor, or by convergence in *Hydrobryum* and *Zeylanidium olivaceum* (Kita & Kato 2001).

4. Hydrobryum bifoliatum C. Cusset, Bull. Mus. Natl. Hist. Nat., B, Adansonia 14(1): 48, f. 10, 1992.

Type: Tung Salaeng Luang, 450 m, Northern Thailand, fl. Feb., *Hansen & Smitinand 11475* (C!). (Fig. 5)

Root crustaceous, irregularly lobed, 0.5-0.7 mm thick; tufts of leaves appressed or oblique; leaves up to 5 per tuft, linear, 3-5 mm long, sheathed at base. Flowering shoots appressed, flowers solitary at tip; bracts uniform, 2-3(-4), linear-lanceolate, gradually narrowed, acuminate, ca. 3 mm long, as high as ovary; spathella smooth on dorsal surface, minutely papillate on ventral surface, irregularly ruptured near apex at anthesis, more or less persistent; ovary stalk (peduncle) 0.5-1 mm long; tepals 2, on both sides of stamen near base of ovary stalk, linear, 2-3 mm long; stamens 2, branched 1/4-1/3 from top, to 5(-7) mm long; ovary locules 2, ellipsoid, to 2.5 mm long; stigmas 2, forked below middle, to 1.3 mm long, unequal (the longer 0.8 mm long from branch point, the shorter 0.4-0.5 mm) or sometimes subequal, the shorter more curved than the longer, linear; ovules on septum surface except in lower central area or on marginal surface of septum, 17-25 per locule; capsule stalked, ellipsoid, flattened, with 14-20.

Distribution: Thailand (Northern, Northeastern [Cusset 1992]).

Notes: Cusset (1992) recorded *Tagawa & Kitagawa T1916* and *T1959* (KYO) collected in Phu Luang, Udawn, Northeastern Thailand as *Hydrobryum bifoliatum*, but I did not examine the specimen.

This species and *Hydrobryum kaensophense* are similar in the acuminate bracts and unequal stigmas, and differ from other species with obtuse or round, rarely acute bract tips and equal stigmas. They form a monophyletic clade (Fig. 1; Kita & Kato 2001, in press). The type specimen examined by Cusset (1992) has young flowers and flower buds. In comparison, in our material the leaves are more numerous and longer, the bracts are 2 or 3 (rarely 4), the stamens are longer than the ovary, the ovary is stalked and larger, and the capsule has more ribs.

Other specimen examined: Northern Thailand: Tung Saleng Luang Natl. Park, Phitsanulok, 16°51'N 100°51'E, 420 m alt., fl. fr. Dec., *Kato et al. TL-310*.

5. Hydrobryum kaengsophense M. Kato, **sp. nov.** (Fig. 6)

H. bifoliati bracteis acuminatis, stigmatibus inaequalibus simile, sed bracteis 4-6 differt.

Type: Kaeng Sopha waterfall, Tung Saleng

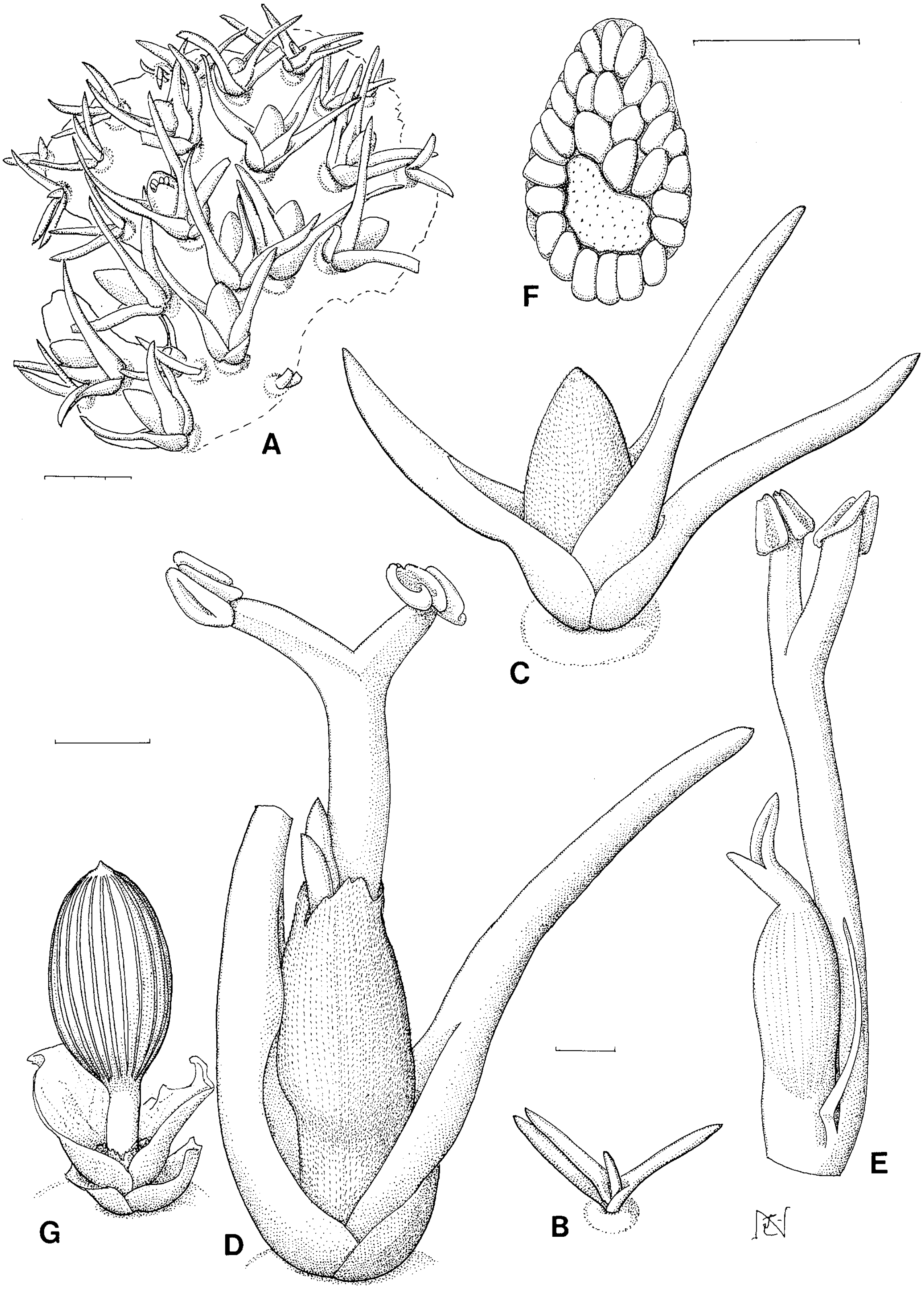

FIG. 5. *Hydrobryum bifoliatum* (*Kato et al. TL-310*). A. Crustaceous root with tufts of leaves and flowering shoots. B. Tuft of leaves. C. Flower bud covered by spathella above bracts. D. Dorsal view of flower at anthesis with most of ovary still covered by spathella. E. Oblique lateral view of flower. Spathella is removed. F. Ovary septum with ovules. G. Fruit. Scales bars = 3 mm for A; 1 mm for B-G.

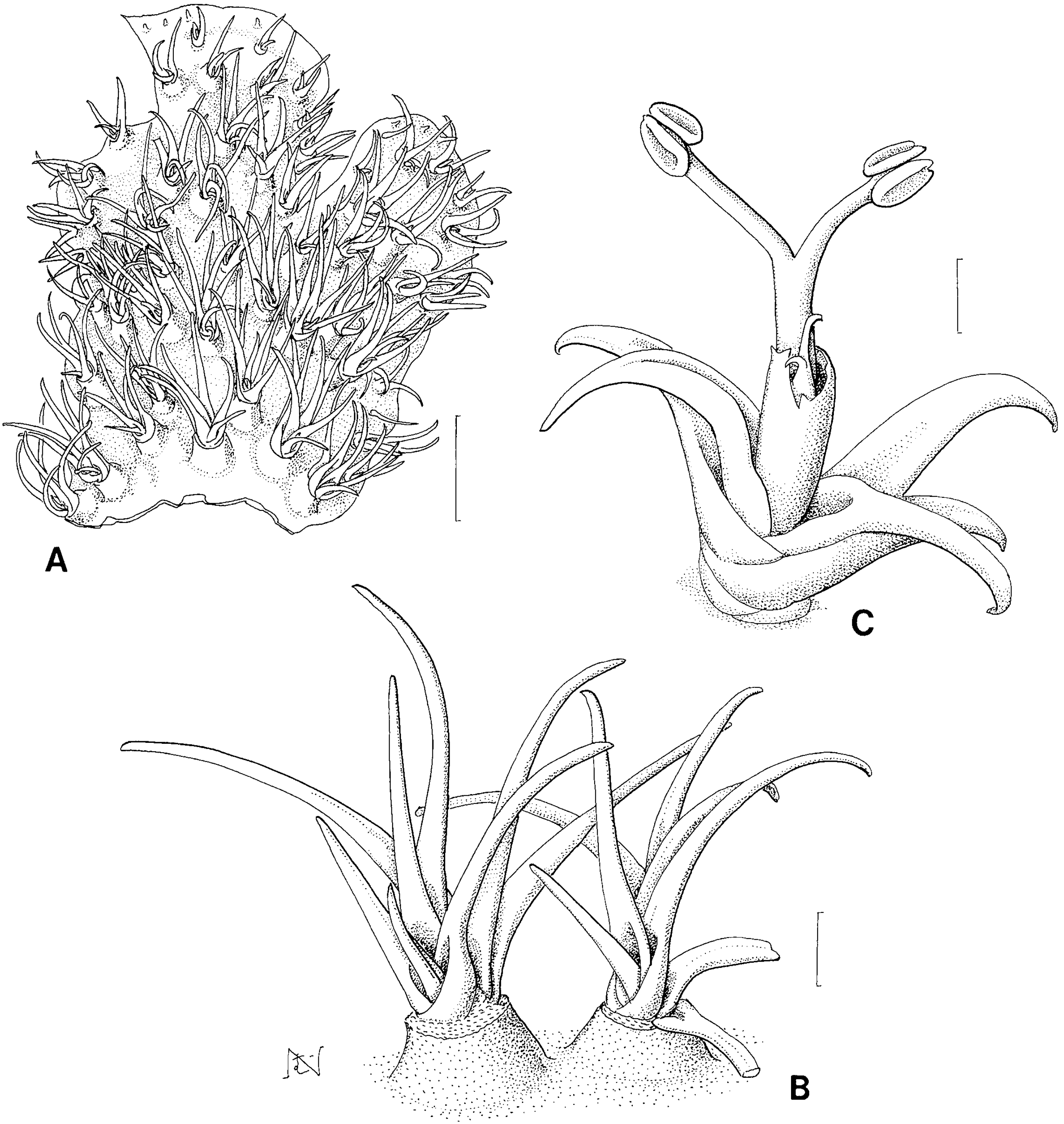

FIG. 6. *Hydrobryum kaengsophense* (*Kato et al. TL-312*). A. Crustaceous root with tufts of leaves on dorsal surface. B. Tufts of leaves surrounded by raised rims of root. Leaves are sheathed at base. C. Flower at anthesis with ruptured spathella above bracts; dorsal view. Scales bars = 5 mm for A; 1 mm for B-C.

Luang Natl. Park, Phitsanulok, Northern Thailand, 16°52'N 100°50'E, 400 m alt., Dec. 25 & 26, 2000, fl., *M. Kato*, *Y. Kita & T. Wongprasert TI-312* (holo BKF; iso TI).

Root crustaceous, 1-1.5 mm thick, irregularly lobed, lobes to 1.5 cm wide; tufts of leaves oblique, surrounded by raised fringe; leaves to 8 per tuft, linear, gradually narrowed to tip, to 8 mm long, 0.6 mm wide, sheathed at base. Flowering shoots appressed, flowers solitary at tip; bracts uniform, 4-6, linear, gradually narrowed, apex acuminate, sheath-like at base, 4-5(-8) mm long, as long as ovary; spathella irregularly ruptured near apex at anthesis; ovary stalk (peduncle) ca. 0.5 mm long; tepals 2, on both sides of stamen, linear; stamens 2, branched at middle, 5-6 mm long, much longer than ovary; ovary locules 2, ellipsoid, ca. 2 mm long; stigmas apparently 1 (especially when young), divided into 2 markedly unequal lobes below or near middle, curved, linear, 0.8-1.5 mm x to 0.3 mm, shorter lobe to half the length of longer lobe, ca. 0.1 mm thick; ovules on septum surface except in lower central area, 16-18 per locule; capsule stalked, ellipsoid, flattened, ribs 12-14.

Distribution: Thailand (Northern).

Notes: This species shares linear, pointed bracts and unequal stigmas with *Hydrobryum bifoliatum* and is its closest relative among the species examined (Fig. 1), although the stigmas of *Hy. kaengsophense* are markedly unequal. On the other hand, the two species differ in that in *Hy. kaengsophense* the bracts are 4-6 and the crust (root) is markedly raised around the tufts of leaves; in *Hy. bifoliatum* the bracts are 2 or 3 (or 4) and the root is slightly raised. The two species occur in the same river but allopatrically.

Other specimen examined: Northern Thailand: Kaeng Sopha waterfall, Tung Saleng Luang Natl. Park, Phitsanulok, 16°52'N 100°50'E, 400 m alt., fl. fr. Dec., *Kato et al. TI-311bis*.

6. Hydrobryum tardhuangense M. Kato, sp. nov. (Fig. 7)

H. bifoliati et *H. kaengsophensis* foliis obliquis, bracteis acutis simile, sed bracteis deltatis, ovariis multo inferioribus, stigmatibus brevioribus (usque ad 0.8 mm longis), subaequalibus, ovulis secus marginem septi differt.

Type: Tard Huang International waterfall, Na Haew Natl. Park, Loei, Northeastern Thailand, 17°34'N 100°59'E, 570 m alt., Dec. 26, 2000, fl., *M. Kato, Y. Kita & T. Wongprasert TL-314* (holo BKF; iso TI).

Root crustaceous, irregularly lobed; tufts of leaves appressed or oblique; leaves to 10 per tuft, needle-like, sheath-like at base, ca. 7 mm long, ca. 0.3 mm thick. Flowering shoots appressed, flowers solitary at tip; bracts uniform, subpapillate, 4-6, deltoid, apex acute, 1.5-2.5 mm long, margins slightly reflexed; flower bud covered by spathella, spathella subpapillate, ruptured longitudinally at anthesis; ovary stalk (peduncle) 0.5 mm long; tepals 2, on both sides of stamen, linear, ca. 2.2 mm long; stamens 2, branched 1/3 from apex, 4-5 mm long; ovary locules 2, ellipsoid, ca. 1.5 mm × 1 mm, much exceeding bracts; stigmas 2, linear, curved, subequal, ca. 0.6 mm long; ovules on marginal surface of septum, sometimes with 1 or few ovules in upper center, 11-17 per locule; capsule stalked, ascending, ellipsoid, ribs 12-14.

Distribution: Thailand (Northeastern).

Notes: The phylogeny showing this species diverging between the clade of *Hydrobryum bifoliatum* and *Hy. kaengsophense* and the rest of *Hydrobryum* (Fig. 1) may be reflected in its intermediate morphology between the two. On the one hand, *Hy. tardhuangense* is similar to *Hy. bifoliatum* and *Hy. kaengsophense* in the oblique leaves and pointed bract. However, it differs from those two in the bract being much lower than the ovary and in the acute bract tip (not sharply pointed to acuminate as in the other two species), the stigma relatively shorter (to 0.8 mm) and subequal, and the ovules borne on the marginal surface of the septum and not in the center. In contrast, *Hy. tardhuangense* is similar to the rest of *Hydrobryum* in the bracts not markedly pointed (acute or obtuse) and in the stigmas being not markedly unequal, but it differs in the leaves being appressed or oblique and the stigmas subequal. *Hydrobryum tardhuangense* occurs along with *Hy. loeicum* in Tard Huang International waterfall, but is morphologically distinct from it in its oblique, non-sheathed leaves (terete or flattened), ovate bracts with round tip, equal stigmas, ovules 4-7 per locule, and the ribs of the capsule 16-20. *Hydrobryum tardhuangense* shares the longitudi-

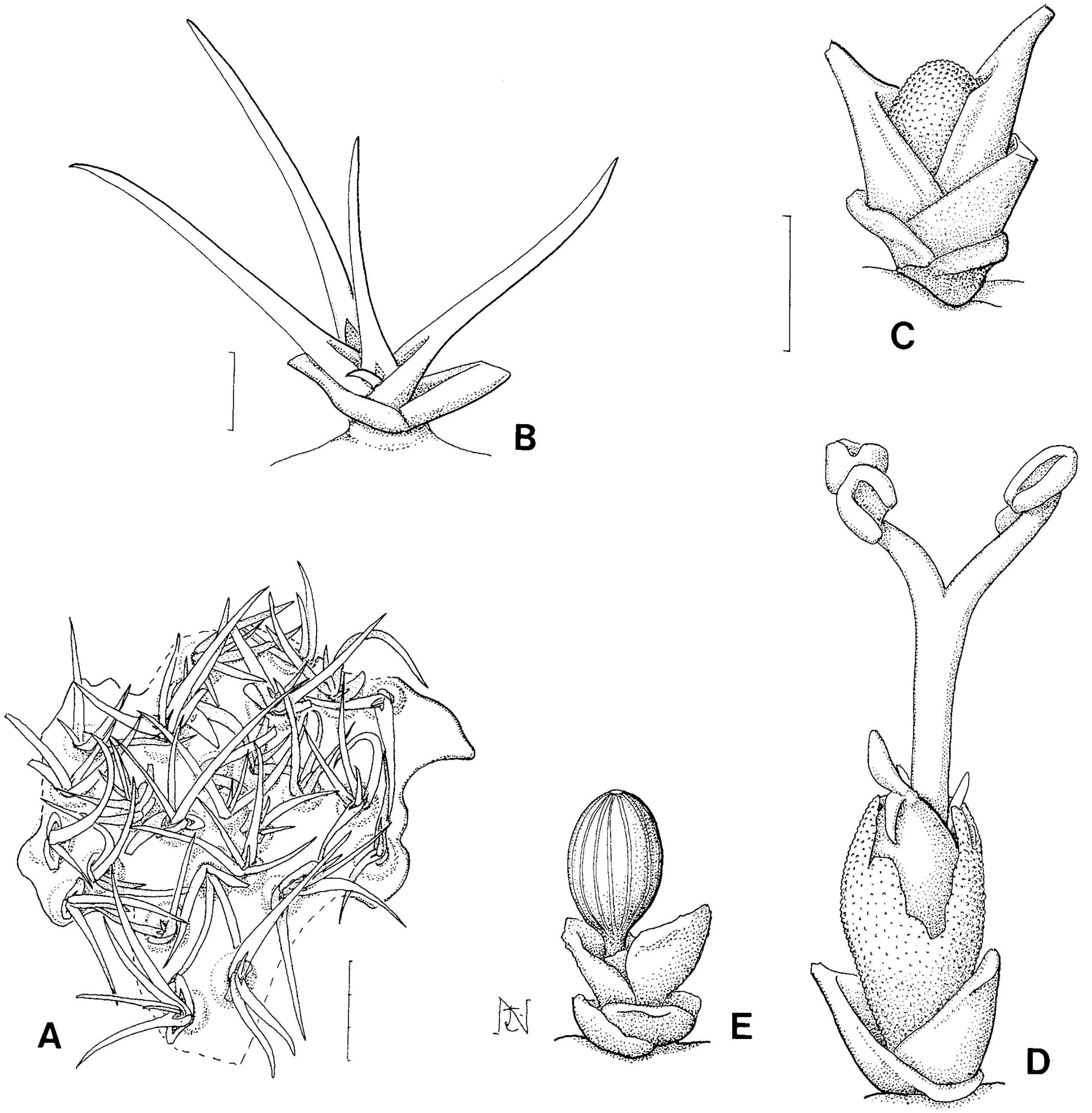

FIG. 7. *Hydrobryum tardhuangense* (A-B, *Kato et al. TL-208*; C-F, *Kato et al. TL-314*). A. Crustaceous root with tufts of leaves on dorsal surface. B. Tuft of leaves with raised rim of root. Leaves are sheathed at base. C. Flower bud covered by spathella between bracts. D. Flower at anthesis; dorsal view. E. Fruit. Scales bars = 3 mm for A; 1 mm for B-E.

nally ruptured spathella with *Hy. somranii*.

Other specimen examined: Northeastern Thailand: Tard Huang International waterfall, Na Haew Natl. Park, Loei, 17°34'N 100°59'E, 570 m alt., st. Sep., *Kato et al. TL-208*.

7. Hydrobryum griffithii (Wall. ex Griff.) Tul., Ann. Sci. Nat., ser. 3, 11: 103, 1849; Arch. Mus. Paris 6: 141, 1852; Tuyama & Hara, J. Jap. Bot. 39: 185, f. 1, 1964; Cusset, Fl. Cambodge, Laos & Viêt-Nam 14: 68, pl. 10, f. 1-6, 1973; Bull. Mus. Natl. Hist. Nat., B, Adansonia 14(1): 45, f. 9, 4-7, 1992; Wu, Fl. Reipubl. Popularis Sin. 24: 4, pl. 1, f. 5, 1988; Kato & Kita, Acta Phytotax. Geobot. 54: 95, 2003—*Podostemum griffithii* Wall. ex Griff., Asiat. Res. 19: 105, tab. 17, 1836.

Type: E. India, Khasya Mts., *Griffith 2436* (holo K!; iso P). (Fig. 8)

Root crustaceous, irregularly lobed, to 10 mm wide or wider; leaves 5-15 per tuft, linear, variable in length, to 10-20 mm long. Flowering shoots appressed, flowers solitary at tip; bracts uniform, (4 or) 5 or 6, ovate, 2-3 mm long, basal ones smaller, (oblong-)ovate, apex subacute or obtuse; spathella irregularly ruptured near apex at anthesis; ovary stalk (peduncle) 0.5-1 mm long; tepals 2, borne above middle of stalk, on both sides of stamen, fused to stamen at base, linear, 2.5-3 mm long; stamens 2, branched about 1/4-1/3 way from tip, 3.5-4.5 mm long, slightly taller than pistil, pale when fresh, pollen pale; ovary locules 2, ellipsoid, ca. 2.5 mm long; stigmas 2, equal, 0.3-0.5 mm long, cristate, pale green when fresh; ovules 22-29 per locule, on septum surface except in small lower central area; capsule shortly stalked, ellipsoid, flattened, ribs 12-14.

Distribution: Thailand (Northern); northern India, Nepal, Bhutan, south-central China (southern Yunnan), northern Vietnam.

Notes: Cusset (1992) referred *Lojtnant & Chawalit Niyomdham 227* (AAU) collected in Chao Sao station, Mae Ai, Chiang Mai, to *Hydrobryum griffithii*, which I did not see among the AAU specimens I examined. Royen (1965) recorded the species based on *Sørensen, Larsen & Hansen 2636* (C) collected in Doi Suthep, Chiang Mai, which was identified as *Hy. japonicum* by Cusset (1992). It is referable to *Hy. chiangmaiense* (see below).

This species is the most widely distributed in *Hydrobryum* and, like *Polypleurum wallichii*, needs intraspecific analysis to understand its taxonomy and geography. It is distinct from most other species of *Hydrobryum* of Thailand in having long leaves (10-20 mm), cristate stigma and numerous ovules (20-30 per locule). It is similar to *Hy. chiangmaiense* in the non-pointed stigma and long leaves, but differs in the stigma and ovules, as described in the notes under *Hy. chiangmaiense*. In *Hy. griffithii* the anthers are close to the stigmas at anthesis, while obviously separate in the other species of *Hydrobryum*. This character may be linked with the breeding system (possibly inbreeding).

Other specimens examined: Northern Thailand: Mae Nam Fang Natl. Park, Chiang Mai, 640 m alt., 19°59'N 99°09'E, st. Sep., fl. fr. Mar., *Kato et al. TL-205, TL-418, TL-803.*

8. Hydrobryum loeicum M.Kato, **sp. nov.** (Fig. 9)

A speciebus congeneribus praeter *H. bifoliatum* capsulis 16-20-costatis differt, *H. japonici* bracteis 4-6, ovatis, stigmatibus aequalibus, linearibus, acutis similissime, sed a quo ovulis in quoque loculo 4-7, a *H. micranthero* staminibus 2, ovario 2-loculato differt.

Type: Tard Huang International waterfall, Huang River, Na Haew Natl. Park, Na Haew Dist., Loei, Northeastern Thailand, 570 m alt., 17°34'N 100°59'E, Dec. 26, 2000, fl. fr., *M. Kato, Y. Kita & T. Wongprasert TL-314bis* (holo BKF; iso TI).

Root crustaceous, irregularly lobed; tufts of leaves patent; leaves 1-4 per tuft, needle-like, terete, to 3 mm long. Flowering shoots appressed, flowers solitary at tip; bracts uniform, (2-)4-6, ovate, 1-1.5 mm long; spathella irregularly ruptured near apex at anthesis; ovary stalk (peduncle) ca. 0.5 mm long; tepals 2, on both sides of stamen, linear, 1.5-2 mm long; stamens 2, branched 1/3 from tip, 3-4 mm long, common andropod (filament) as long as ovary; ovary locules 2, ellipsoid, 1.7-2 mm long; stigmas 2, equal, 0.4 mm long, linear, pointed, more or less curved; ovules on marginal surface of septum, 4-8 per locule; capsule stalked (0.7-1.5 mm long), ellipsoid, flattened, ribs 16-20.

Distribution: Thailand (Northeastern).

Notes: This species is very similar to *Hydrobryum japonicum* in having 4-6 ovate bracts, 2 stamens with a forked filament, and equal, linear, pointed stigmas, but differs from it in the fewer (4-

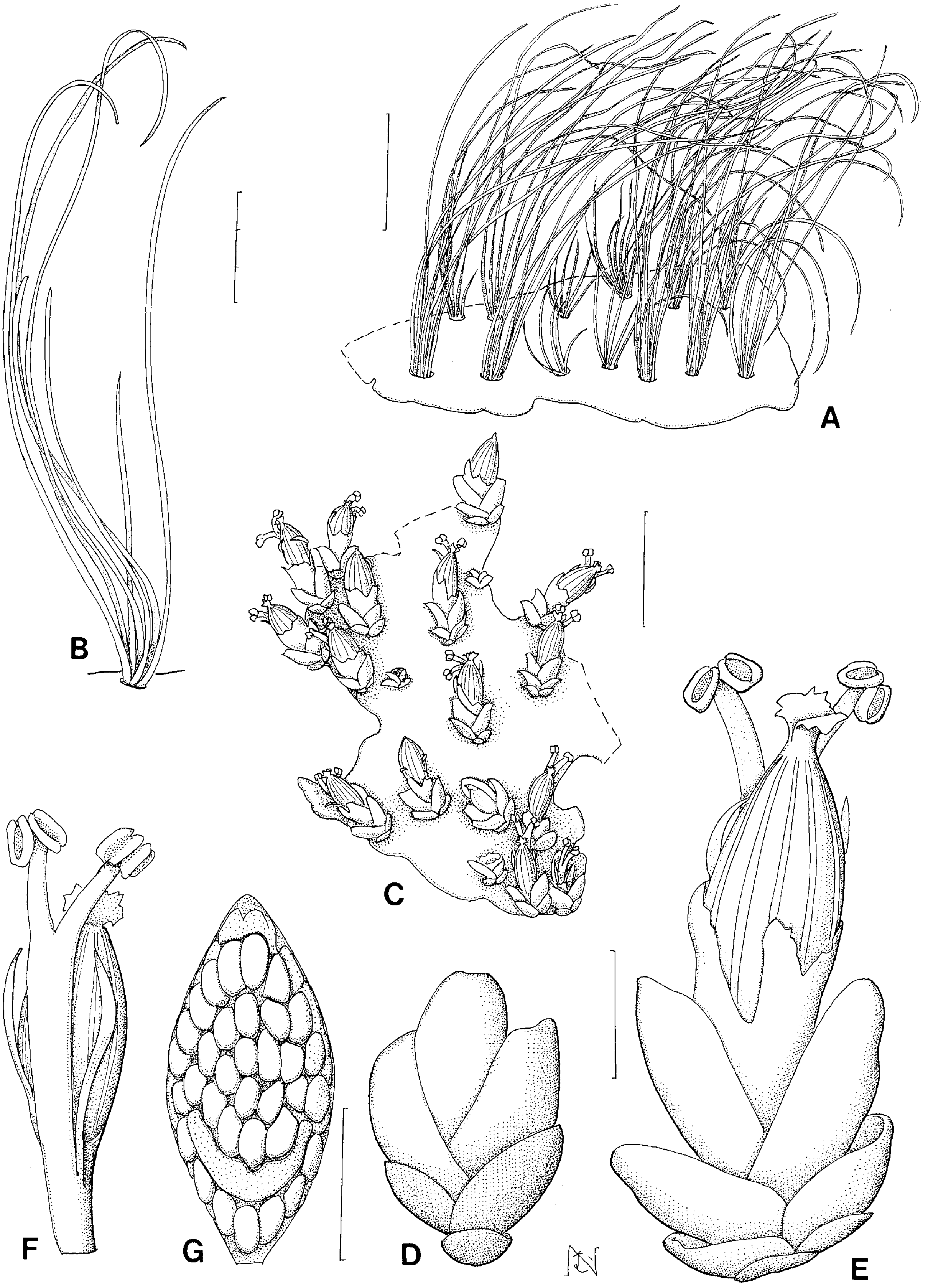

FIG. 8. *Hydrobryum griffithii* (A-B, *Kato et al. TL-205*; C-G, *Kato et al. TL-418*). A. Crustaceous root with tufts of leaves on dorsal surface. B. Tuft of leaves. C. Root with flowering shoots. D. Flower bud covered by spathella. E-F. Dorsal (E) and ventral (F) views of flowers at anthesis. G. Ovary septum with ovules. Scales bars = 5 mm for A, C; 3 mm for B; 1 mm for D-G.

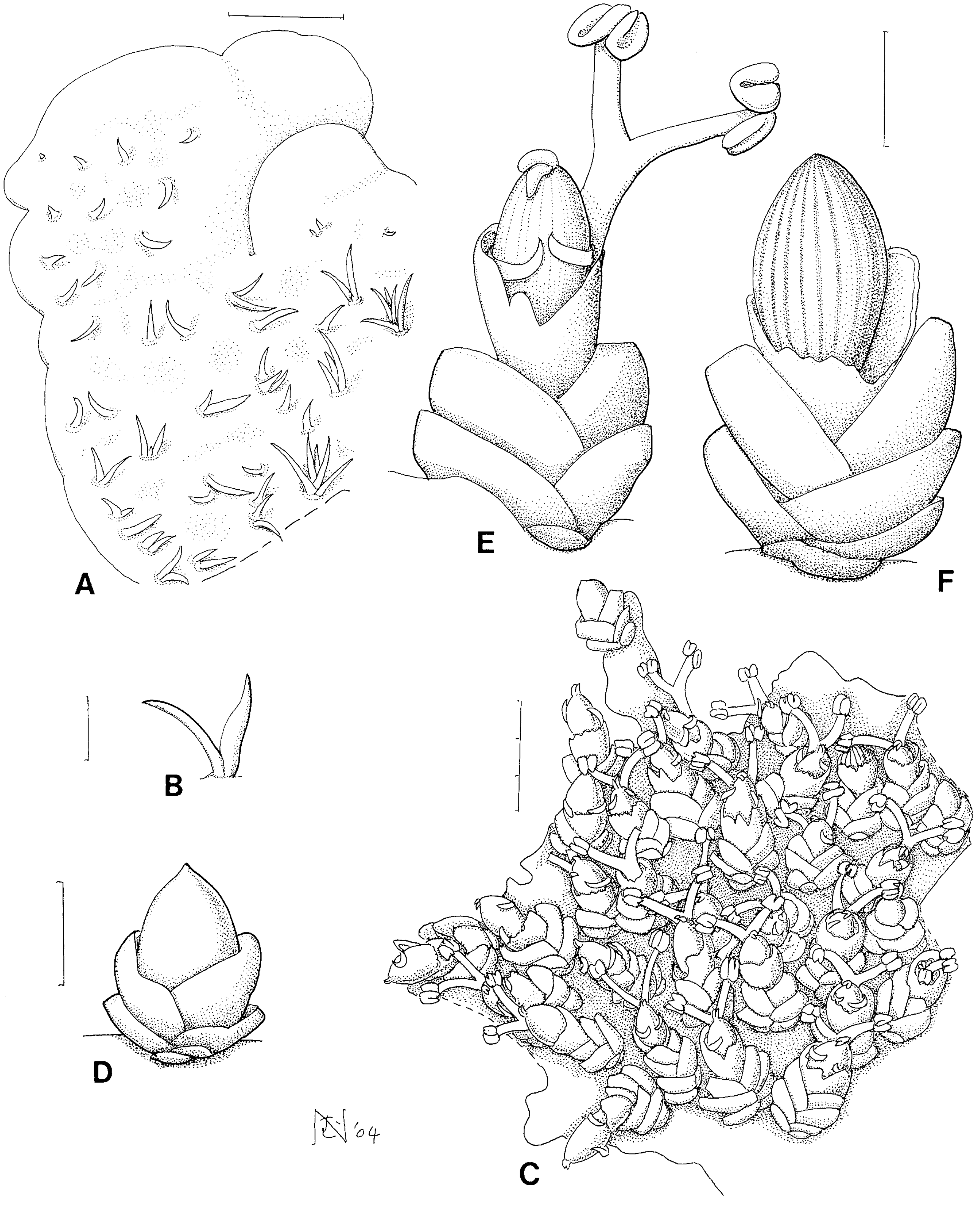

FIG. 9. *Hydrobryum loeicum* (*Kato et al. TL-314bis*). A. Crustaceous root with tufts of leaves on dorsal surface. B. Tuft of leaves. C. Flowering shoots on root. D. Flower bud covered by spathella above bracts. E. Flower at anthesis; dorsal view. F. Fruit. Scales bars = 5 mm for A; 1 mm for B, D-F; 3 mm for C.

8) ovules per locule and more (16-20) ribs on capsules of similar size. In the relatively fewer, larger ovules the species is similar to *Hanseniella heterophylla* and *Ha. smitinandii*. Phylogenetically, *Hy. loeicum* is most closely related to *Hy. micrantherum* rather than to other congeneric species (Fig. 1), although *Hy. loeicum* is morphologically similar to *Hy. japonicum*, as noted above, and distinct from *Hy. micrantherum* in the number of stamens (2 *vs.* 1) and ovular locules (2 *vs.* 1).

A plant (*TL-1102*) from the Tadphramba waterfall is identified to be conspecific with the type by diagnostic characters. In comparison, the molecular difference is large (Y. Kita unpubl. data), suggesting that different populations have changed little morphologically for a long time after divergence.

Other specimens examined: Northeastern Thailand: Tard Huang International waterfall, Huang River, Na Haew Natl. Park, Na Haew Dist., Loei, 570 m alt., 17°34'N 100°59'E, st. Sep., *Kato et al. TL-208bis*; Khae stream, Loei, 755 m alt., 17°29'N 100°57'E, st. Sep., fl. fr. Dec., *M. Kato et al. TL-209*, *Kato et al. TL-316*; Khae stream, Loei, 755 m alt., 17°29'N 100°57'E, st. Sep., fl. buds Dec., *Kato et al. TL-210*; Khring waterfall, Loei, 635 m alt., 17°28'N 100°59'E, st. Sep., fl. fr. Dec., *Kato et al. TL-211*, *TL-317*; Huenganga waterfall near Tard Huang International waterfall (Na Haew Natl. Park), Loei, 17°34'N 100°58'E, 620 m alt., fl. Dec., *Kato et al. TL-315*; Tadphramba waterfall, Nam Nao Natl. Park, Phechabun, 750 m alt., 16°45'N 101°39'E, fl. fr. Feb., *Kato & Wongprasert TL-1102*.

9. Hydrobryum somranii M.Kato, sp. nov. (Fig. 10)

H. bifoliati bracteis 2 simile (congenericis ceteris differt), sed bracteis ovatis, ovario 1-loculato, stigmatibus aequalibus differt; *H. khaoyaiensi* bracteis 2-4, ovatis simile, sed ovario 1-loculato, staminibus 1 differt; *H. micrantheri* var. *micrantheri* et var. *crassi* bracteis 2-4, ovario 1-loculato simile, sed staminibus 2 differt.

Type: Tad Kham waterfall, Phu Langka Natl. Park, Nakhon Phanom, Northeastern Thailand, 150 m alt., 17°57'N 104°09'E, Feb. 24, 2003, fl. fr., *M. Kato & T. Wongprasert TL-703* (holo BKF; iso TI).

Root crustaceous, irregularly lobed; leaves few per tuft, filiform, to 7 mm long. Flowering shoots appressed, flowers solitary at tip; flowers appressed in bud, erect at anthesis; bracts uniform, 2-4, lower ones reduced, ovate, to 1.3 mm long, rough; spathella shortly papillate, ruptured longitudinally at anthesis (due to upturning of peduncle); ovary stalk (peduncle) 1-2 mm long; tepals 2, on both sides of stamen, linear, 1-2 mm long; stamens borne above base or near middle of stalk, 2, branched above middle, ca. 5(-6) mm long, much longer than ovary; ovary locule 1, with septum free from ovary wall at flanks and attached at distal and proximal ends, ellipsoid, ca. 2 mm long; stigmas 2, forked near base, equal, 0.3-0.6 mm long, ligulate, entire, narrowed and blunt at tip; ovules on marginal surface of septum, 6-12 per septum; capsule erect, stalked (stalk 1-2.5 mm long), 1.5-2.5 mm long, ellipsoid, flattened, ribs 12-14.

Distribution: Thailand (Northeastern).

Notes: Molecular data show that *Hydrobryum somranii* is most closely related to *Hy. griffithii* and *Hy. chiangmaiense* rather than to *Hy. micrantherum* (Fig. 1; Y. Kita unpubl. data). It differs from the former two, however, in the fewer (2-4) bracts, ligulate, entire stigmas, and in particular in the unilocular ovary. *Hy. somranii* can be distinguished from all other species by the erect flowers borne on the appressed shoot. It is similar to *Hy. bifoliatum* in the two large bracts (although the additional basal bracts are reduced) but differs in the ovate bracts and equal stigmas. *Hy. somranii* is also similar to *Hy. japonicum* and to some other species in the ovate bracts and equal, linear, entire stigmas, while different from them in the longitudinally ruptured spathella. In the ovate bracts, *Hy. somranii* differs from *Hy. tardhuangense* with likewise longitudinally ruptured spathellas. In the longitudinally rupturing spathellas *Hy. somranii* is further similar to

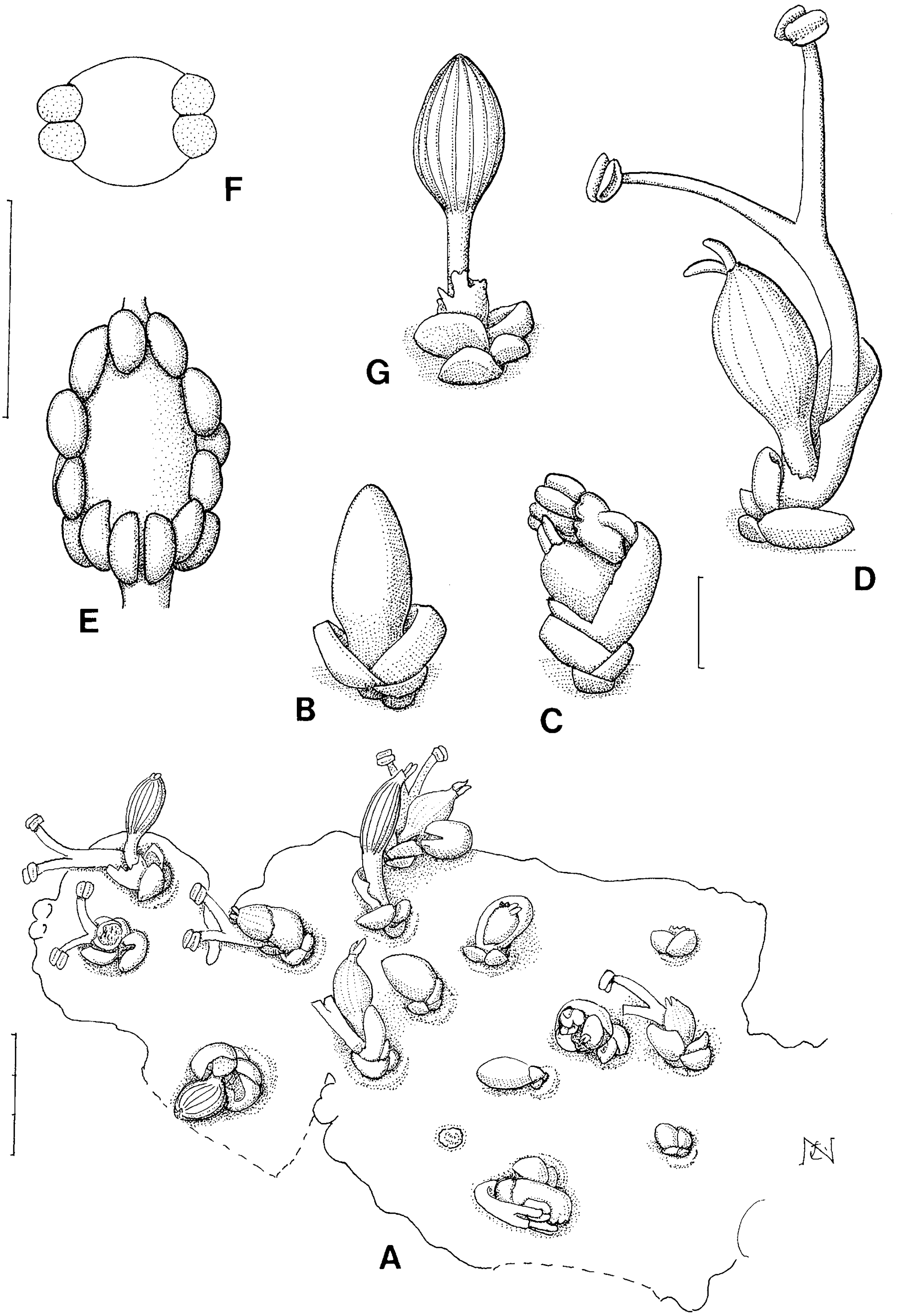

FIG. 10. *Hydrobryum somranii* (*Kato & Wongprasert TL-703*). A. Crustaceous root with flowering shoots on dorsal surface. B. Flower bud covered by spathella above bracts. C. Young flower. D. Flower at anthesis with spathella split longitudinally. E. Ovary septum with ovules at margins. F. Cross section of septum with ovules, showing reduced septum margins. G. Fruit. Scales bars = 3 mm for A; 1 mm for B-G.

the crustaceous-rooted *Diplobryum minutale* and *D. vientianense* (Kato & Fukuoka 2002), but the phylogenetic relationships of the latter two species is uncertain. The spathella ruptures longitudinally due to the upturning elongation of the peduncle, which is short and appressed to the root surface in the flower bud.

In the unilocular ovary *Hydrobryum somranii* is similar to *Hy. micrantherum*, while different in the number of stamens (forked and two in the former, and simple and one in the latter). Because of the non-sister group relationship, the unilocular ovaries are derived independently.

The species epithet *somranii* is dedicated to Dr. Somran Suddee who collected the species for the first time, and, along with other collections, contributed much to a better understanding of the Podostemaceae of Thailand.

Other specimens examined: Northeastern Thailand: Tad Kham waterfall, Phu Langka Natl. Park, Nakhon Phanom, 150 m alt., 17°57'N 104°09'E, fl. fr. Jan., *Somran Suddee 1743*; Tad Pho waterfall, Phu Langka Natl. Park, Nakhon Phanom prov., 190 m alt., 17°59'N 104°08'E, fl. fr. Feb., *Kato & Wongprasert TL-704*.

10. **Hydrobryum chiangmaiense** M.Kato, **sp. nov.** (Fig. 11)

H. griffithii foliis longissimis simile, sed stigmatibus apice truncatis, emarginatis vel obtusis, bracteis 4, ovulis in quoque loculo usque 20 differt. *H. japonici* bracteis 4 simile, sed foliis usque 20 mm longis, stigmatibus non-linearibus, ovulis septum obducentibus differt.

Type: Pha Mon waterfall, Doi Inthanon Natl. Park, Chang Mai, Northern Thailand, 18°33'N 98°34'E, 900 m alt., Dec. 27, 2001, fl. fr., *M. Kato, S. Koi, Y. Kita & T. Wongprasert TL-424* (holo BKF; iso TI).

Root crustaceous, irregularly lobed, various in size, to 10 mm wide, in populations at high altitudes (1,100-1,300 m) to 2 mm wide; leaves 5-15 per tuft, filiform, to 10-20 mm long. Flowering shoots appressed, flowers solitary at tip; bracts uniform, 4(-6), ovate, 1-1.5 mm long, basal bracts sometimes filiform like leaves; spathella often papillate, irregularly ruptured near apex at anthesis; ovary stalk (peduncle) ca. 0.5-1.5 mm long; tepals 2, on both sides of stamen, fused to stamen at base, linear, 1-2 mm long; stamens inserted around middle of ovary stalk, 2, branched 1/4-2/5 from tip, 2-3.5(-4.5) mm long, anther white when fresh; ovary locules 2, ellipsoid, 2-2.5 mm long; stigmas 2, forked near base, equal, 0.3-0.5 mm long, subentire or shallowly undulate, truncate, obtuse or emarginate at tip, often reddish when fresh; ovules on septum surface except in lower central area, 12-20 per locule; capsule stalked (stalk 1-1.5 mm long), 2-2.5 mm long, ellipsoid, flattened, ribs 12-14.

Distribution: Thailand (Northern).

Notes: This species shares long, filiform leaves with *Hydrobryum griffithii*, which is sister in the molecular phylogeny (Fig. 1). *Hydrobryum griffithii* differs from it in the cristate stigmas, 5 or 6 larger bracts and more (22-29) ovules. *Hy. japonicum*, which sometimes occurs in the same rivers, differs in that the stigma is linear and pointed at the tip, and the ovules are borne only on the marginal surface of the septum.

The crustaceous root is variable in this species, and in particular, populations at Huai Sai Lueng waterfall (*Kato et al. TL-429*) at 1100 m altitude and Siriphon waterfall (*Kato et al. TL-423*) at 1300 m, Doi Inthanon Natl. Park, Chiang Mai, appear very different from those in other localities. Their root lobe is 2-4 mm wide, thin, and tightly adherent to the rock surface, and the leaf is long (up to 10 mm) relative to root width.

Cusset (1992) treated *Sørensen et al. 2636* (C), Doi Suthep, Chiang Mai, as *Hyrdobryum japonicum*, but I identified it as *Hy. chiangmaiense*, based on the diagnostic characters in the Key.

Royen (1965) recorded *Zeylanidium lichenoides* from Doi Suthep, Chiang Mai, based on *Sørensen et al. 2908* (C, not seen). It is distributed

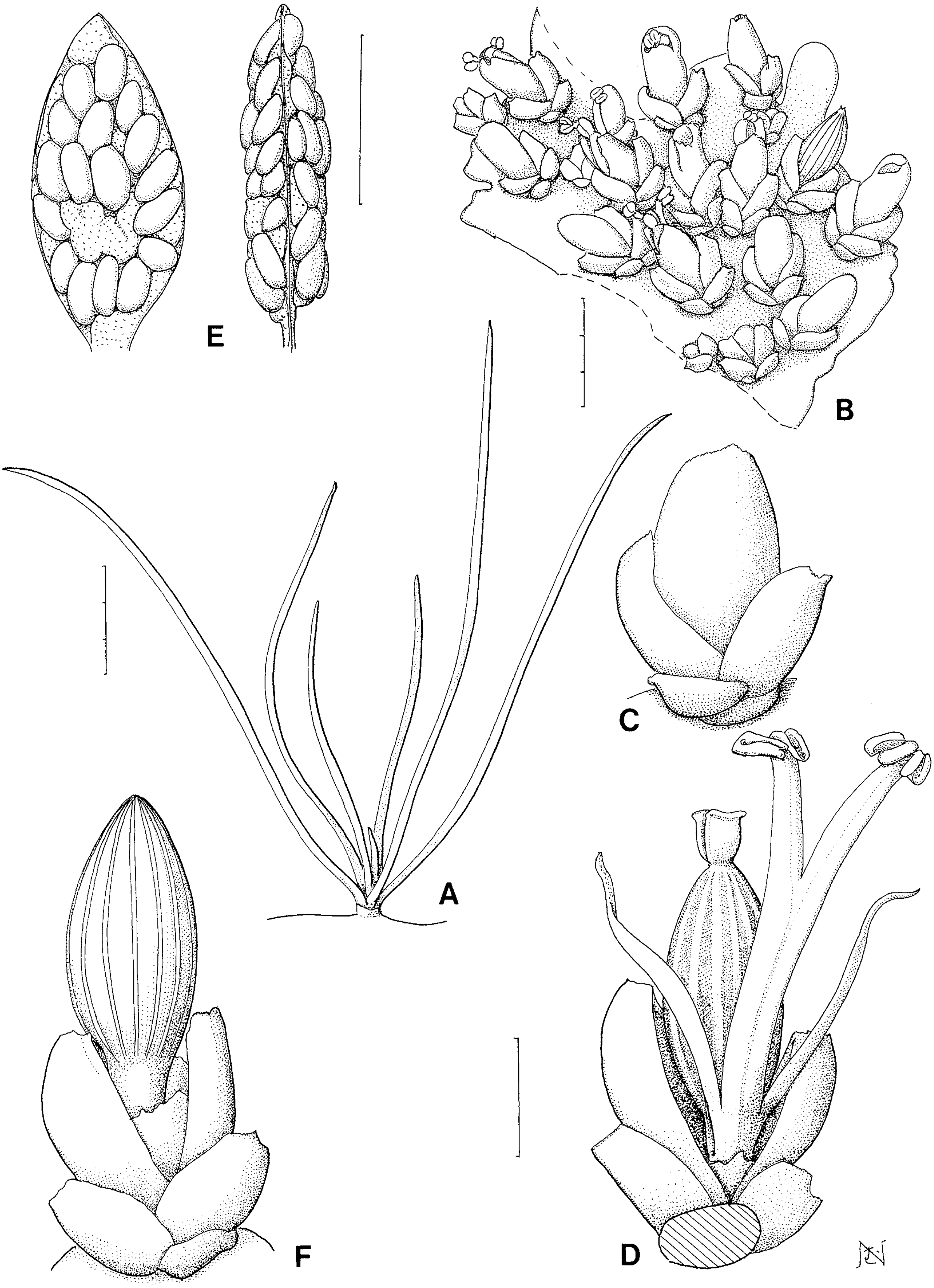

FIG. 11. *Hydrobryum chiangmaiense* (*Kato et al. TL-424*). A. Tuft of leaves. B. Crustaceous root with flowering shoots on dorsal surface. C. Flower bud covered by spathella above bracts. D. Flower at anthesis with ruptured spathella; ventral view. Cross section of shoot base is seen. E. Ovary septum with ovules; surface and side views. F. Fruit. Scales bars = 3 mm for A-B; 1 mm for C-F.

in Myanmar, northern and southern India, and Sri Lanka. In *Z. lichenoides* the root is broadly ribbon-like, the tufts of leaves and flowering shoots are borne at the branching points of the root, and the capsule has 8 ribs and dehisces by 2 unequal valves. The specimen may be *Hydrobryum chiangmaiense*, which occurs abundantly at Doi Suthep and Doi Inthanon.

Other specimens examined: Northern Thailand: Montharan waterfall, Doi Suthep, Chiang Mai, 700 m alt., 18°49'N 98°55'E, st. Jan., st. fl. Dec., *Kato et al. TL-63*, *TL-430*, *TL-431*, *TL-432*; Doi Suthep, Chiang Mai, 400 m alt., fl. fl. buds, Apr., *Sørensen et al. 2636* (C); Wachiratharn waterfall, Doi Inthanon, Chiang Mai, 600-700 m alt., 18°32'N 98°36'E, fl. fr. Dec., fl. buds Jan., *Kato et al. TL-64*, *TL-421*, *TL-422*; 23 km point from junction of route 108 and mountain road, 955 m alt., 18°32'N 98°34'E, Doi Inthanon Natl. Park, Chiang Mai, fl. fr. Jan., *Kato et al. TL-65*; Siriphon waterfall near National Park Headquarters, 1300 m alt., 18°33'N 98°31'E, Doi Inthanon Natl. Park, Chiang Mai, st. Dec., *Kato et al. TL-423*; Mae Pan waterfall, 1000 m alt., 18°32'N 98°27'E, Doi Inthanon Natl. Park, Chiang Mai, st. fl. buds Dec. *Kato et al. TL-426bis*, *TL-427*; Mae Pan waterfall, 1000 m alt., 18°32'N 98°27'E, Doi Inthanon Natl. Park, Chiang Mai, fl. fr. Dec., *Kato et al. TL-428*; Huai Sai Lueng waterfall, 1100 m alt., 18°31'N 98°27'E, Doi Inthanon Natl. Park, Chiang Mai, fl. fr. Dec., *Kato et al. TL-429*; Wang Kwai waterfall above Mae Klang waterfall, Doi Inthanon Natl. Park, Chiang Mai, 450 m alt., 18°30'N 98°40'E, fr. Mar., *Kato et al. TL-805*; Forest Fire Protection Main Office, Doi Inthanon Natl. Park, Chiang Mai, 800 m alt., 18°32'N 98°36'E, fl. fr. Mar., *Kato et al. TL-806*; Siritharn waterfall, 900 m alt., 18°33'N 98°36'E, Doi Inthanon Natl. Park, Chiang Mai, fl. fr. Mar., *Kato et al. TL-807*; Poomuen waterfall, Mai Ai, Chiang Mai, 800 m alt., 20°01'N 99°11'E, fl. fr. Mar., *Kato et al. TL-801*.

11. Hydrobryum japonicum Imamura, Bot. Mag. Tokyo 42: 376, 1928; l.c. 43: 332, 1929; Ohwi, Fl. Jap. 394, 1965; Shin, Wild Fl. Jap. Herb. Pl. 2: 214, 1982; Cusset, Bull. Mus. Natl. Hist. Nat., B, Adansonia 14(1): 46 1992, *p.p. excl. H. floribundum* (Koidz.) Koidz. *et H. puncticulatum* Koidz.— *Hydroanzia japonica* (Imamura) Koidz., Acta Phytotax. Geobot. 4: 28, 1935.

Type: *Senokuchi s.n.* (TI, not seen), Ohnejime, Kagoshima, Kyushu, Japan. (Fig. 12)

Root crustaceous, irregularly lobed, with tufts of leaves patent; leaves ca. 10 per tuft, needle-like, 2-6 mm long. Flowering shoots appressed, flowers solitary at tip; bracts in 2 ranks, uniform, 4 or 5, ovate, convex; spathella irregularly ruptured near apex at anthesis; ovary stalk (peduncle) short; tepals 2, on both sides of stamen, inserted near base of stalk, linear-lanceolate, ca. 2 mm long; stamens 2, branched below middle, to 5 mm long, much longer than ovary, purple-red or pale when fresh, pollen yellow; ovary locules 2, ellipsoid, 2-2.5 mm long, septum fissured above sterile thick central area; stigmas 2, equal, 0.6-1(-1.3) mm long, linear, pointed or obtuse at tip, branched above base, often reflexed, purple-red when fresh; ovules (8-)11-15(-16) per locule, on marginal surface of septum; capsule shortly stalked (to 0.5 mm long), ellipsoid, flattened, ribs 12-14.

Distribution: Thailand (Northern, Northeastern; Central [Cusset 1992]), south-central China (Kato & Kita 2003), Japan (southwestern).

Notes: This is most similar to *Hydrobryum chiangmaiense* in the numbers of bracts (4[-6]) and capsule ribs (12-14) and stamens (2), (sub)equal entire stigmas, as Cusset (1992) identified *Sørensen et al. 2636* (= *Hy. chiangmaiense*) as *Hy. japonicum*. Differences from *Hy. chiangmaiense* are shown above in the notes under that species. Cusset (1992) recorded the species from northeastern (*Tagawa, Iwatsuki & Fukuoka s.n.* [KYO] from Phu Luang) and central Thailand (*Iwatsuki & Fukuoka s.n.* [KYO], *Kai Larsen s.n.* [AAU], both from Khao Yai) (neither of them seen), as well as northern Thailand; further field research is necessary.

Thai populations are most closely related to the Japanese populations rather than to the south-central Chinese (Yunnan) population (Kita & Kato in press), and *Hydrobryum japonicum* is close to Japanese *Hy. floribundum*, *Hy. koribanum* and *Hy. yakushi-*

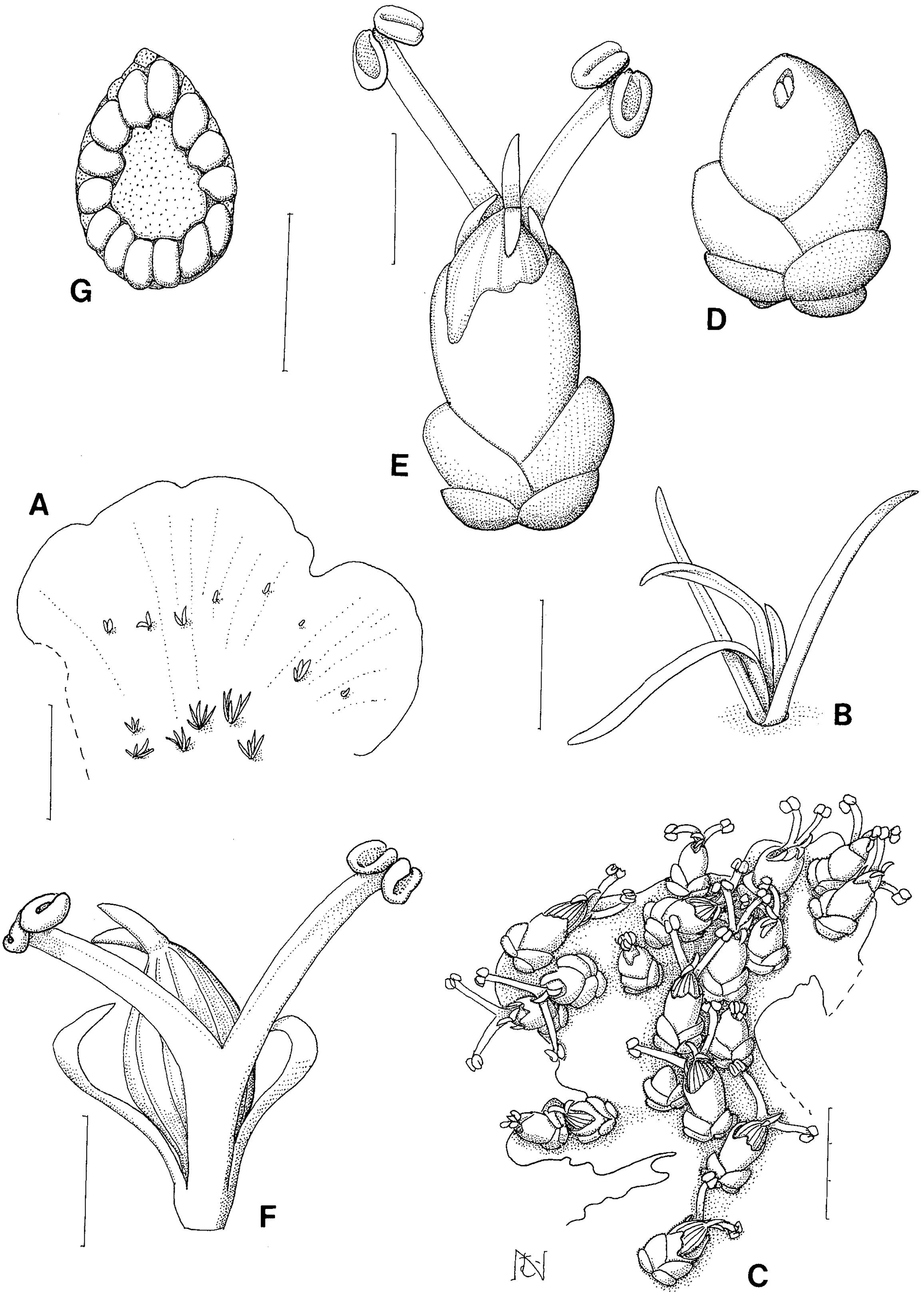

FIG. 12. *Hydrobryum japonicum* (A-B, *Kato et al. TL-415*; C-G, *Kato et al. TL-426*). A. Crustaceous root with tufts of leaves on dorsal surface. B. Tuft of leaves. C. Root with flowering shoots. D. Flower bud covered by spathella above bracts. E-F. Dorsal (E) and ventral (F) views of flowers at anthesis. G. Ovary septum with ovules. Scales bars = 5 mm for A; 1 mm for B, D-G; 3 mm for C.

mense (Fig. 1). Taking this relationship into account, the distribution pattern is unusual in that *Hy. japonicum* is disjunct between Thailand, south-central China, and Japan, although potential habitats are available and other Podostemaceae occur in the intervening regions (Kato & Kita 2003). Kita & Kato (in press) argued that the disjunct distribution is due to three dispersal events. The earliest dispersal occurred northward to give rise to a distribution pattern similar to the present one, followed by two events, one dispersal from Japan to Yunnan and the other most recent dispersal from Japan to northern Thailand. This scenario is distinct from that of *Cladopus*, although the earliest dispersal event is common in both genera (Kita & Kato, in press).

Specimens examined: Northern Thailand: Mae Nam Fang Natl. Park, Chiang Mai, 680 m alt., 19°59'S 99°09'E, st. Sep, fl. fr. Dec., *Kato et al. TL-206*, *TL-207*, *TL-415*, *TL-416*, *TL-417*; Fang, Chiang Mai, fr. Feb., *Smitinand 4251* (C); Mae Sop Aep stream, 500 m alt., 18°32'N 98°36'E, Doi Inthanon Natl. Park, Chiang Mai, fl. st. Dec., *Kato et al. TL-420*; Mae Pan waterfall, 1000 m alt., 18°32'N 98°27'E, Doi Inthanon Natl. Park, Chiang Mai, fl. fr. Dec., *Kato et al. TL-426*; Nan prov., Amphoe Chiang Klang, E of Ban Hang Thung, along Road 1097, 600 m alt., 19°20'E 100°47'E, fl. fr. Nov., *Larsen 44512* (AAU); Mae Wang stream, north of Doi Inthanon Natl. Park, Chiang Mai, 450 m alt., 18K38'N 98°43'E, fl. Dec., *Kato et al. TL-1004*; Mae Laka river, Ban Nong Haeng, Khoon Yuam District, 174 km point from Hot, Mae Hongson, 480 m alt., 18°39'N 97°56'E, fl. fr. Dec., *Kato et al. TL-1006*; Sobwak village, Mae Chaem, Chiang Mai, 550 m alt., 18°39'N 98°23'E, fl. Mar., *Kato & Wongprasert TL-1201*; Pang Ma Pha, Mae Hong Son, 620 m alt., 19°31'N 98°15'E, fl. fr. Mar., *Kato & Wongprasert TL-1203*; Hmopaeng waterfall, Pai District, Mae Hong Son, 870 m alt., 19°23'N 98°23'E, fl. Mar., *Kato & Wongprasert TL-1204*. Northeastern Thailand: Nam Phrom, Chaiyaphum Dist., 600 m alt., 16°20'N 101°45'E, *van Beusekon et al. 4089* (K); None Phatana village, Phu Luang Wildlife Res., Loei, 560 m alt., 17°09'N 101°28'E, fl. fr. Feb., *Kato & Wongprasert TL-1103*.

12. **Hydrobryum khaoyaiense** M.Kato, **sp. nov.** (Fig. 13)

H. micranthero stamine singulari, simplici simile, sed foliis longioribus, tenicibus, ovario 2-loculato differt.

Type: Haew Narok waterfall, Khao Yai Natl. Park, Nakawn Nayok, Central Thailand, 14°17'N, 101°23'E, 400 m alt., fl. fr., Dec. 24, 2000, *M. Kato, Y. Kita & T. Wongprasert TL-307* (holo BKF; iso TI).

Root crustaceous, irregularly lobed; leaves ca. 5 per tuft, needle-like, flattened, 2-3.5 mm long, somewhat tough, curved. Flowering shoots appressed, flowers solitary at tip; bracts uniform, ovate, 2 or 3 (or 4), basal bracts sometimes distally needle-like, ca. 1 mm long; spathella flattened, irregularly ruptured near apex in dorsal half at anthesis; ovary stalk (peduncle) ca. 1 mm long; tepals 2, on both sides of stamen near base of ovary stalk, linear, ca. 2 mm long; stamens 1, to 4 mm long including anthers, much longer than ovary; anther 0.7-0.8 mm long, white; ovary green when fresh, locules 2, ellipsoid, ca. 1.6 mm × 1 mm, ovules on marginal surface of septum, placentation axile, 17-23 per locule; stigmas 2, forked near base, equal, linear-lanceolate, ca. 0.5-0.6 mm long, curved, pointed; capsule stalked (stalk 0.5-1 mm long), ellipsoid, ribs 12-14.

Distribution: Thailand (Central).

Notes: This species agrees with *Hydrobryum micrantherum* in the single stamen, but differs from it in the longer, tough leaves, fewer (2 or 3) bracts, and bilocular ovary (axile placentation). In the internal ovary structure it agrees with other species of *Hydrobryum* (except *Hy. somranii* with unilocular ovaries). These differences, however, do not reflect the very close molecular phylogenetic relationship of *Hy. khaoyaiense* and *Hy. micrantherum* (Fig. 1).

Other specimen examined: Central Thailand: Haew Narok waterfall, Khao Yai Natl. Park, Nakawn Nayok, 360 m alt., 14°17'N 101°24'E, st. fl. buds, Jan., fl. Dec., *Kato et al. TL-59*, *Kita & Wongprasert TL-401*.

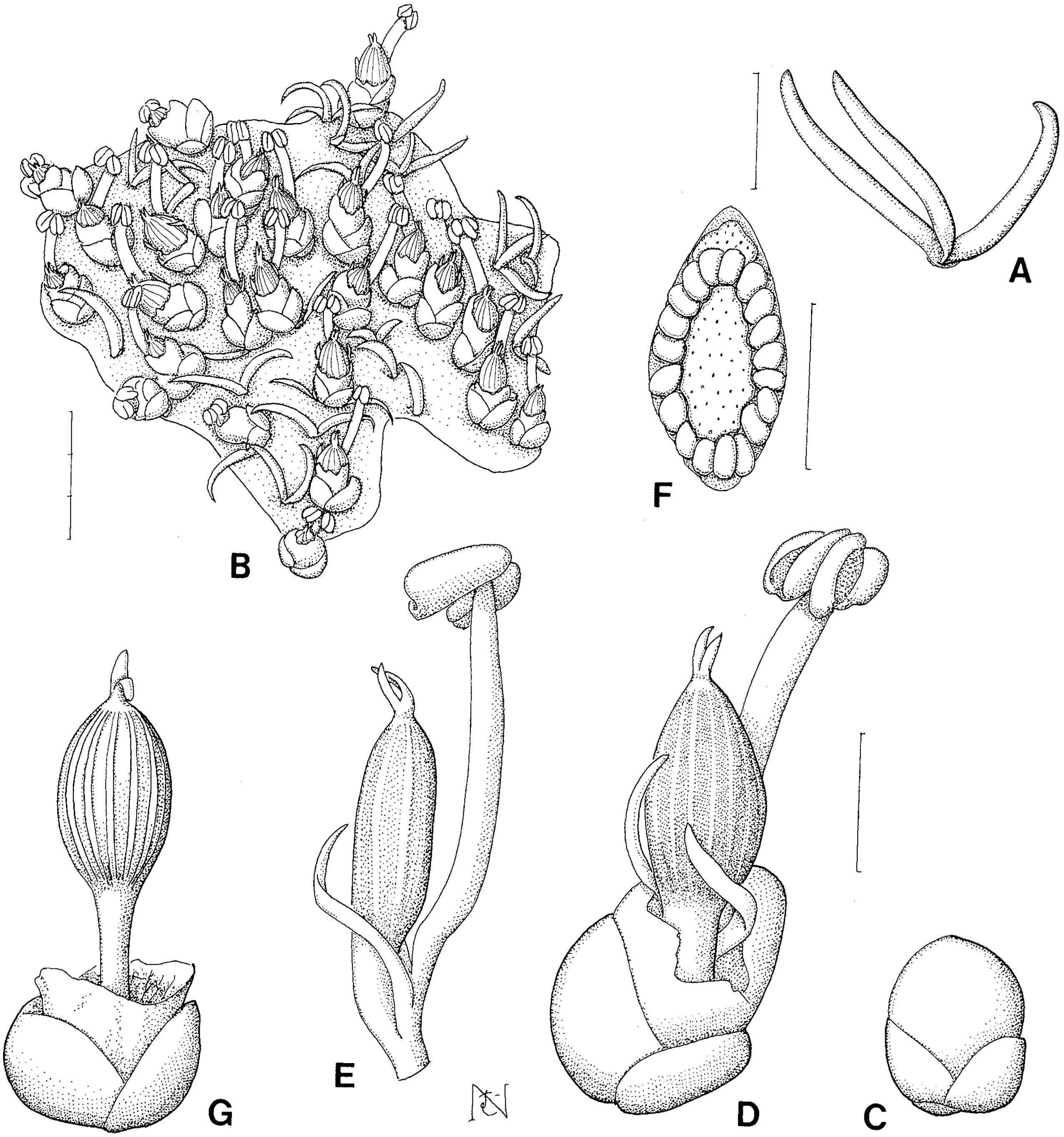

FIG. 13. *Hydrobryum khaoyaiense* (*Kato et al. TL-307*). A. Tuft of leaves. B. Crustaceous root with flowering shoots. C. Flower bud covered by spathella above bracts. D-E. Dorsal (D) and lateral (E) views of flowers at anthesis. F. Ovary septum with ovules. G. Fruit. Scales bars = 1 mm for A, C-G; 3 mm for B.

13. Hydrobryum micrantherum (P.Royen) C.D.K.Cook & Rutish., Taxon 50: 1165, 2001—*Polypleurella micranthera* P.Royen, Blumea 8: 522, f. 1, 1957—*Synstylis micranthera* (P.Royen) C.Cusset, Bull. Mus. Natl. Hist. Nat., B, Adansonia 14(1): 28, f. 4, 1-7, 1992.

Type: Khao Soi Dao, SE Chanthaburi, 600 m alt., Southeastern Thailand, fl. fr. Jan., *Smitinand 3185* (L!).

13a. var. **micrantherum** (Fig. 14)
Root crustaceous, irregularly lobed, 0.1-0.2 mm thick; leaves to 5 per tuft, needle-like, to 1.5 mm long. Flowering shoots appressed, flowers solitary at tip; bracts uniform, ovate, 2-4; spathella flattened, irregularly ruptured near apex in dorsal half at anthesis; ovary stalk (peduncle) to ca. 1.2 mm long; tepals 2, on both sides of stamen, inserted above base of stalk, linear, ca. 2 mm long; stamen 1, to 5 mm long, much longer than ovary; ovary locule

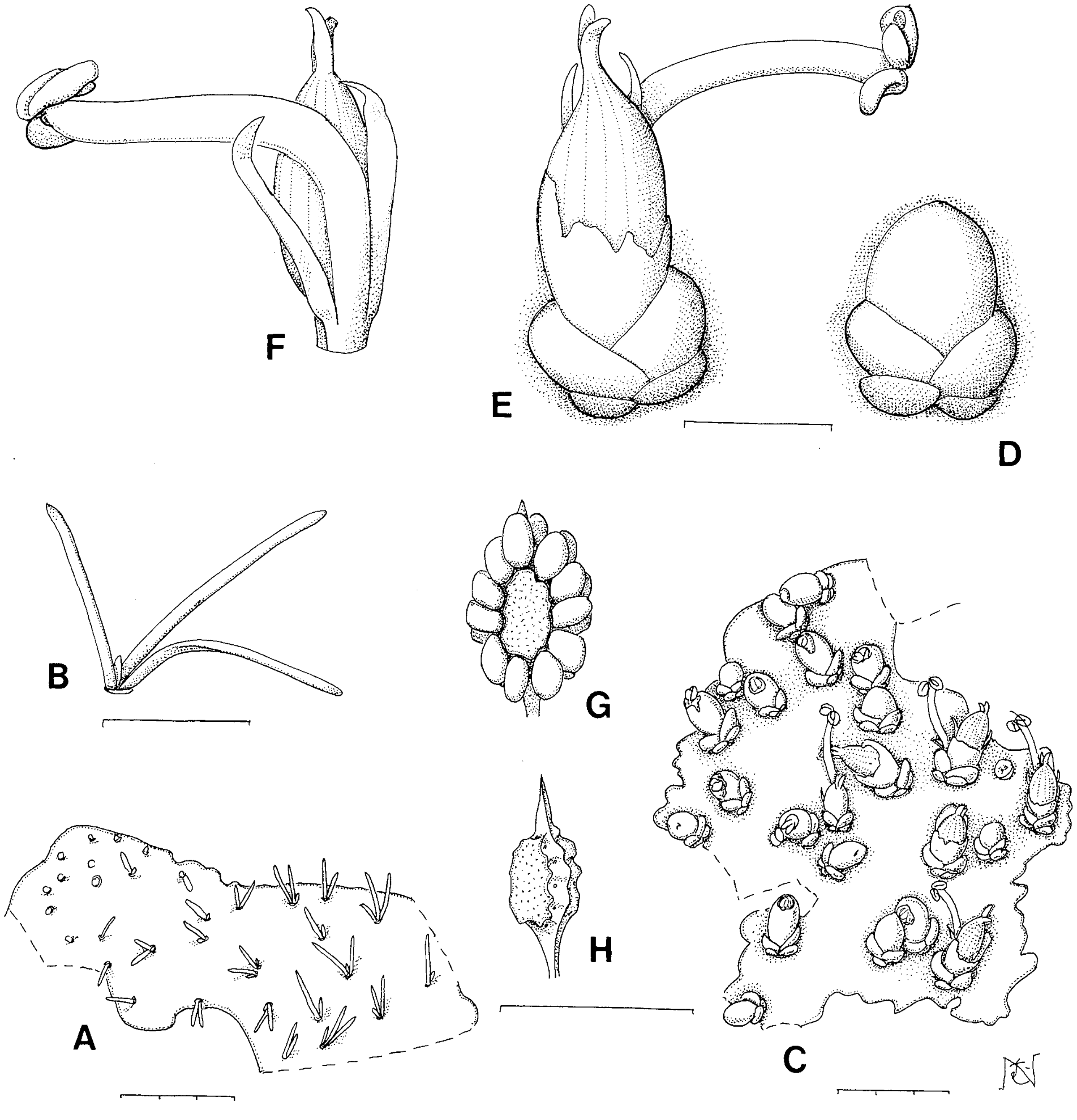

FIG. 14. *Hydrobryum micratherum* var. *micrantherum* (*Kato et al. TL-62*). A. Crustaceous root with tufts of leaves. B. Tuft of leaves. C. Flowering shoots on root. D. Flower bud covered by spathella above bracts. E-F. Dorsal (E) and ventral (F) views of flowers at anthesis. G. Ovary septum with ovules. H. Oblique lateral view of ovary septum with lateral margins reduced. Ovules are removed. Scales bars = 3 mm for A, C; 1 mm for B, D-H.

1, with septum connected to ovary wall at distal and proximal ends and free at blanks, ellipsoid, ca. 1.5 mm × 1 mm; ovules on reduced margin of septum, 9-13 on each face, placentation pseudo-central; stigmas 2, forked near base, equal, linear-lanceolate, ca. 0.5-0.7 mm long; capsule stalked (stalk 0.5-1 mm long), ellipsoid, ribs 12-14.

Distribution: Thailand (Southeastern; Northern [Cusset 1992]).

Notes: This species was originally described as a second species of *Polypleurella* that had been defined as having a single stamen (Royen 1957). Later, Cusset (1992) established the new genus *Synstylis* for it, characterized by the pseudo-central placentation (unilocular ovary) as well (Royen 1957), while synonymizing *Polypleurella* under *Polypleurum* and recognizing *P. schmidtianum*. Cook & Rutishauser (2001) combined *S. micranthera* with *Hydrobryum*, based on non-unilocular (bilocular) placentation (but this description is incorrect) and molecular phylogeny (Kita & Kato 2001). This treatment is supported by recent molecular data (Fig. 1; Kita & Kato in press) that *Hy. micrantherum* is nested within *Hydrobryum* and most closely related to *Hy. loeicum*, thereby supporting the combination. The ovary of our materials collected from the type and other localities is unilocular with a septum connected to the ovary wall at the distal and proximal ends and free on the sides, so the placentation is pseudo-central (Royen 1957, fig. 1; Cusset 1992). Unilocular ovaries with pseudo-central placentation also occur in *H. somranii* and in a species of *Polypleurum*, which usually has bilocular ovaries and axile placentation (M. Kato, unpublished data).

Cusset (1992) identified *Smitinand 3765* (L), collected in Fang, Chiang Mai, Northern Thailand, as *Hydrobryum* (= *Synstylis*) *micrantherum*. It is too old (with capsules) to identify with ease (T. Yamada, pers. commun.). Royen (1965) also recorded the species from Northern Thailand, and further research is needed.

Other specimens examined: Southeastern Thailand: Khao Soi Dao Nira, fl. fr. Feb., *Jacobsen 77-2* (C); Khao Soi Dao, Chanthaburi, 400-450 m alt., fl. Jan. *Kato et al. TL-62*; Khao Soi Dao, Chanthaburi, ca. 900 m alt., fr. Feb., *P. Phonsena s.n.* (BKF).

13b. var. **crassum** M.Kato, **var. nov.** (Fig. 15)

A var. *micranthero* radicibus crassis, ovariis majoribus, ovulis fere duplicibus differt.

Type: Pha Kluaimai waterfall and Haew Suwat waterfall, 700 m alt., Khao Yai Natl. Park, Nakawn Nayok, Central Thailand, Jan. 10, 1999, fl., *M. Kato, R. Imaichi, T. Santisuk & T. Wongprasert TL-57* (holo BKF; iso TI).

Root crustaceous, irregularly lobed, 0.2-0.3 mm thick; leaves 2-4 per tuft, needle-like, 1.5-2.5 mm long. Flowering shoots appressed, flowers solitary at tip; bracts uniform, ovate, 3-5; spathella flattened, irregularly ruptured near apex in dorsal half at anthesis; ovary stalk (peduncle) ca. 1.2 mm long; tepals 2, on both sides of stamen, inserted around or below middle of stalk, linear, ca. 2 mm long; stamen 1, to 5 mm long, much longer than ovary; ovary locule 1, ellipsoid, 1.5-2 mm long, ovules on reduced marginal surface of septum, 13-23 on each septum, placentation pseudo-central; stigmas 2, forked near base, equal, linear-lanceolate, ca. 0.5-0.7 mm long, bluntly pointed; capsule stalked (stalk 0.5-1 mm long), ellipsoid, ribs 12-14.

Distribution: Thailand (Central).

Notes: This variety differs from var. *micrantherum* in the thicker root, larger flower (bracts 3-5, ovary 1.5-2 mm long, ovules 13-23), but is hardly distinguished in other characters (e.g. single stamen, unilocular ovary).

Other specimens examined: Central Thailand: Kong Kaeo waterfall, Khao Yai Natl. Park, Nakawn Nayok, 750 m alt., 14°26'N 101°22'E, st. fl. Jan., *Kato et al. TL-58*; Pha Kluamai waterfall, Khao Yai Natl. Park, Nakawn Nayok, 400 m alt., 14°25'N 101°24'E, fl. Dec., *Kita & Wongprasert TL-403*; Sarika waterfall, 14°18'N 101°15'E, 100 m alt., st. Dec., *Kato et al. TL-306*; Suwat waterfall, Khao Yai Natl. Park, Nakhon Ratchasima, 650 m alt., fl.

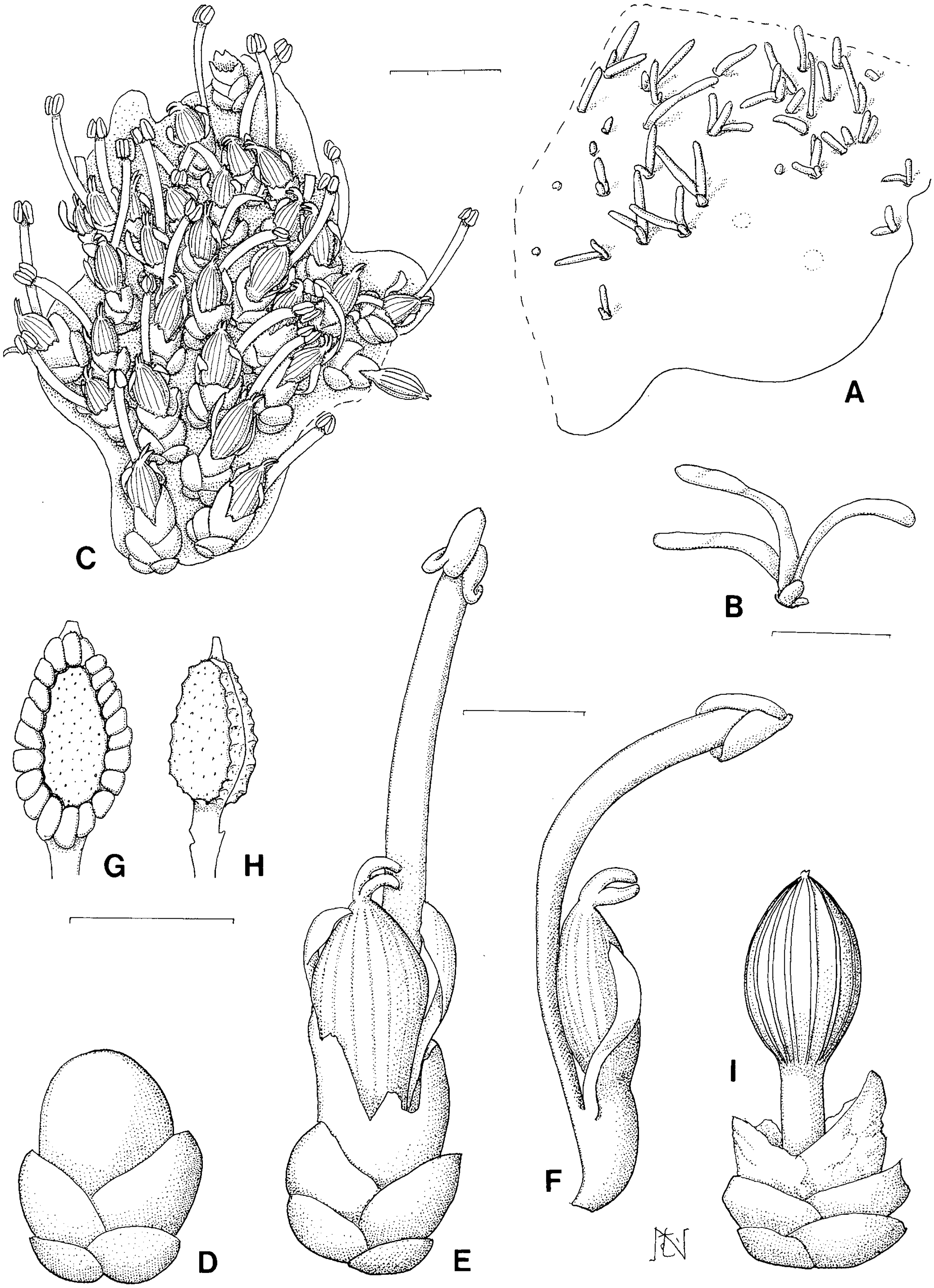

FIG. 15. *Hydrobryum micratherum* var. *crassum* (A-B, *Kato et al. TL-58*; C-I, *Kato et al. TL-57*). A. Crustaceous root with tufts of leaves. B. Tuft of leaves. C. Flowering shoots on root. D. Flower bud covered by spathella above bracts. E-F. Dorsal (E) and lateral (F) views of flowers at anthesis. G. Ovary septum with ovules. H. Oblique lateral view of ovary septum with lateral margins reduced. Ovules are removed. I. Fruit. Scales bars = 3 mm for A, C; 1 mm for B, D-I.

buds, Mar., *Lambinon 87-82* (AAU); Administration Center, Khao Yai Natl. Park, Nakhon Nayok / Nakhon Ratchasima, 780 m alt., fr. Mar., *Lambinon 87-64* (AAU).

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